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Troisième Conférence Internationale
sur les Zones Humides d'INTECOL
Rennes 1988

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LA TROISIÈME CONFÉRENCE INTERNATIONALE SUR LES ZONES HUMIDES D'INTECOL RENNES, 1988

Jean-Claude LEFEUVRE
Organisateur de la Conférence

Ne couvrant qu'environ 6% de la surface des continents, les zones humides sont cependant parmi les écosystèmes les plus importants de notre planète. L'essentiel de l'économie du globe, le développement industriel et agricole actuel, ne dépendent-ils pas en effet de l'énergie fossile produite et préservée par les grands marécages du Carbonifère ? (MITSCH et GOSSELINK, 1986). Les recherches effectuées depuis près d'un demi siècle sur les zones humides n'ont fait que renforcer l'idée qu'elles sont « les reins du paysage, en raison des fonctions qu'elles remplissent dans les cycles hydrologiques et chimiques et parce qu'elles reçoivent en aval les effluents d'origine naturelle et humaine » (id., 1986). Mais si les scientifiques s'accordent pour reconnaître le rôle fondamental qu'elles jouent dans des domaines aussi variés que l'épuration des eaux polluées, la recharge des aquifères, la prévention des crues, la régularisation des débits des fleuves et des rivières, la protection des rivages, etc., force est de constater que partout dans le monde le drainage, la poldérisation, l'assèchement, les extractions minières et les forages pétroliers, le remblaiement et l'urbanisation font disparaître chaque année des milliers d'hectares de zones humides. La France, pour sa part, draine ou assèche chaque année plus de 120 000 hectares de sols hydromorphes dont des surfaces importantes de prairies humides, de marais salés, de marais doux, de plaines inondables, de zones rivulaires et même de tourbières, milieux déclarés pour la plupart d'intérêt international par la diversité biologique qu'ils entretiennent.

Très tôt, l'attention de la communauté scientifique internationale a été attirée par les changements importants qui affectent ces zones. En effet, leur régression entraîne des répercussions en chaîne sur la gestion des ressources en eau ou sur celle des stocks halieutiques exploitables en eaux douces ou en eaux marines côtières. Régression conduisant également au déclin des populations d'oiseaux d'eau migrateurs, traits d'union entre les nations et de ce fait éléments du patrimoine mondial. Un vaste mouvement d'opinion s'est fait jour, destiné à protéger les zones

humides et à enrayer leur disparition. Il s'est organisé à l'initiative de la France dès 1964 lors de la réunion internationale des Saintes-Marie-de-la-Mer, dont les conclusions préluèrent à la Convention Internationale de Ramsar (1972), véritable charte de conservation des zones humides reconnue et signée par 61 pays en 1990 (517 sites).

Parallèlement, a été largement perçue la nécessité d'intensifier les recherches sur ces systèmes écologiques formant transition entre terre et eaux douces ou marines, soumis à des changements saisonniers et interannuels parfois de grande ampleur, évoluant en permanence dans l'espace et dans le temps. En effet, les zones humides constituent des modèles privilégiés pour tester et affiner des hypothèses majeures en écologie du paysage :

1) l'importance des relations intersystèmes et du poids des activités humaines dans le fonctionnement, la dynamique et l'évolution des écosystèmes ;

2) les propriétés particulières des réseaux et le rôle des corridors dans une problématique d'extinction-colonisation. Véritables « membranes biologiques et physiques » à l'interface de la terre et de l'eau, ces milieux permettent également de matérialiser un type d'écotone et d'analyser certaines de ses propriétés.

Espaces menacés, les zones humides ont suscité l'intérêt des protecteurs ; modèles écologiques passionnants, elles ont suscité celui des scientifiques de différentes disciplines. Elles ont ainsi fédéré un ensemble de recherches exceptionnellement riche, restitué dans de multiples colloques dont les premiers datent de plus de vingt ans. Depuis dix ans, sous l'impulsion du groupe de travail « zones humides »¹ d'Intecol (*Association internationale des sociétés d'écologie*), une conférence internationale réunit tous les quatre ans les spécialistes de la question. La première a été organisée en 1980 à New-Delhi sous la responsabilité du docteur B. GOPAL, la seconde s'est déroulée en Tchécoslovaquie à l'initiative du docteur J. KVEIT.

La Troisième conférence internationale sur les zones humides a été organisée à Rennes (France) par le

¹ Groupe Wetlands d'Intecol en 1990 : MM. DAY, GOPAL, KVEIT, LARSON, LEFEUVRE, MALIBY, MITSCH, & TURNER.

Laboratoire d'évolution des systèmes naturels et modifiés du Muséum national d'histoire naturelle et de l'Université de Rennes. 392 participants représentaient 43 nations sur le thème « Conservation et développement : gestion intégrée des zones humides ». Les sujets suivants ont été traités au cours de huit sessions :

- Session 1.1** - Plaines d'inondation en région tropicale.
- Session 1.2** - Plaines d'inondation en région tempérée.
- Session 2** - Tourbières.
- Session 3** - Zones humides littorales.
- Session 4.1** - Agriculture et zones humides en région tropicale.
- Session 4.2** - Agriculture et zones humides en région tempérée.
- Session 5** - Pêche, aquaculture et zones humides.
- Session 6** - Restauration, création de zones humides.

Deux ateliers ont été consacré l'un aux méthodes d'évaluation des zones humides, l'autre à l'information et l'éducation.

Un premier volume édité par le Muséum National d'Histoire Naturelle en 1989² a regroupé les allocutions de bienvenue et les discours d'ouverture (14), les textes des posters présentés (103), les synthèses rédigées par les présidents de séance et leurs rapporteurs pour chaque session et atelier (10) et, en ce qui concerne les communications orales, uniquement les résumés (93).

Les textes des communications ont été soumis au comité de rédaction international de cette Conférence, constitué par les présidents de session (J.K. BOWERS, R. CARBENIER, E.S. CLAIRAIN, J.W. DAY, M. DECAMPS, J.S. LARSON, E. MALBY, E. TURNER, R.L. WELCOMME, A.J. WHITTEN). Quarante-cinq communications ont été retenues pour publication. Afin d'assurer une diffusion bien ciblée des résultats scientifiques présentés, il a été

décidé de les soumettre pour publication à l'UICN (pour ce qui concerne la gestion des zones humides en zone tropicale), à une revue internationale spécialisée (*Wetland Ecology and Management*), et à une revue d'écologie (*Bulletin d'Écologie*) :

— vingt et une communications appliquées à la gestion et à la valorisation des zones humides en région tropicale, concernant les pays en voie de développement, seront publiées par l'Alliance Mondiale pour la Nature (UICN, Union internationale pour la conservation de la nature et des ressources naturelles) en 1991 ;

— vingt-huit communications ont été acceptées en première lecture par *Wetland Ecology and Management*. Le nombre de communications définitivement acceptées et les délais de correction détermineront les modalités de publication ;

— sur vingt-cinq communications soumises au *Bulletin d'Écologie*, treize ont été retenues. Cinq d'entre elles traitent de l'aquaculture et de la gestion des stocks exploitables de poissons en région tempérée ou tropicale, cinq portent sur la connaissance et la gestion des zones humides en vue de leur exploitation et de leur conservation, trois concernent les modalités de restauration de ces milieux.

La Quatrième conférence internationale sur les zones humides d'INTECOL sera organisée en 1992 (14-18 septembre) à Columbus (Ohio, USA), par William J. MITSCH (The Ohio State University). Le choix de la ville de Columbus a été en partie dicté par le fait que de grandes manifestations se dérouleront en 1992 sur l'ensemble du territoire américain pour fêter le 500^e anniversaire de la découverte des « Amériques » par Christophe Colomb qui, d'après l'histoire, n'aborda la terre ferme qu'après avoir traversé des marismas, des zones humides.

² Lefeuve J.-C. (éd.), 1989. Troisième Conférence Internationale sur les Zones Humides. Third International Wetlands Conference. Conservation et développement : gestion intégrée des zones humides. Paris, Muséum National d'Histoire Naturelle. 371 p.

INTECOL'S THIRD INTERNATIONAL WETLANDS CONFERENCE RENNES, 1988

Jean-Claude LEFEUVRE
Conference Organizer

Although covering only about 6 % of the continents' surface, wetlands are among our planet's most important ecosystems. The greater part of the globe's economy, as well as its industrial and agricultural development indeed depend on the fossil energy produced and preserved by the « swampy environment of the Carboniferous Period » (MITSCH & GOSSELINK, 1986). Research carried out on wetlands over the last half century have reinforced the idea that they are « *the kidneys of the landscape* » for the functions they perform in hydrologic and chemical cycles and as the downstream receivers of wastes from both natural and human sources. » (id., 1986). Scientists agree on their fundamental role in areas as different as the cleansing of polluted waters, recharge of groundwater aquifers, flood prevention, regulation of rivers, protection of shoreline, etc. And yet everywhere in the world drainage, polderisation, mining and oil prospecting, embankment and urbanisation use up thousands of hectares of wetlands. Each year France alone drains more than 120,000 hectares of wetlands including large areas of fresh water and salt marshes, flood plains, riverine wetlands as well as peatlands, most of which are declared of international importance for the biological diversity they sustain.

Early on, the attention of the scientific community was drawn to the important changes affecting these zones. This regression affects management of water resources or exploitable fisheries of fresh or coastal salt waters. It also leads to the decline of migratory water birds which, in bridging nations, are a part of world heritage. There is now a great drive to protect wetlands and limit their regression. This began in France as early as 1964 during the international meeting at Saintes-Marie-de-la-Mer, which set the groundwork for the International Ramsar Convention (1972), a veritable charter of wetland conservation approved and signed by 61 nations in 1990 (517 sites).

At the same time it was recognised that more research was necessary on these systems, which are transitional between land and salt or freshwater, submitted to sometimes great seasonal or interannual changes, and permanently dynamic in space and time. Indeed, wetlands are ideal models for testing and refining major hypotheses in landscape ecology :

- 1) the importance of intersystem relations and the weight of human activities on the function, dynamics and evolution of ecosystems ;

- 2) the particular properties of networks and the role of corridors in the problematic of extinction colonisation. Veritable « biological and physical membranes » where land meets water, these environments also allow to materialise a type of ecotone and to analyse some of the properties related to it.

As threatened environments, wetlands have aroused the interest of conservationists and, as fascinating ecological models, the interest of scientists from many different fields. The latter have formed exceptionally rich groups of research, and have met at several conferences over the last twenty years. For ten years now through Intecol's wetlands work group, an international conference brings together these specialists every four years. The first of these conferences was organized in New-Delhi in 1980 by Doctor B. GOPAL and his team. The second was held in Checkoslovakia on the initiative of Doctor KVET.

The Third International Conference on Wetlands was organized at Rennes (France) by the Laboratoire d'Evolution des systèmes naturels et modifiés of the Muséum national d'histoire naturelle and the Université de Rennes. There were 392 participants representing 43 nations on the theme « Conservation and development : the sustainable use of wetland resources ». Eight sessions treated the following subjects :

- Session 1.1** - Floodplains in tropical regions.
- Session 1.2** - Floodplains in temperate regions.
- Session 2** - Peatlands.
- Session 3** - Coastal lagoons.
- Session 4.1** - Agriculture in tropical wetlands.
- Session 4.2** - Agriculture in temperate wetlands.
- Session 5** - Fisheries, aquaculture and wetlands.
- Session 6** - Restoration, creation of wetlands.

There were also two workshops; one on methods of evaluating wetlands, the other on information and education.

A first volume was edited by the Muséum national d'histoire naturelle in 1989. It contained the welcome and opening speeches (14), the texts of the posters presented (103), summaries of the sessions and workshops by the presidents and reporters of each (10), and summaries of the oral communications (93).

The papers were examined by the Conference's international revision committee, composed of the session presidents (J.K. BOWERS, R. CARBENIER, E.S. CLAIRAIN, J.W. DAY, M. DECAMPS, J.S. LARSON, E. MALBY, E. TURNER, R.L. WELCOMME, A.J. WHITTEN). Forty-five papers were chosen for publication. In order to ensure a well targeted diffusion of the scientific results, it was decided that they would be submitted for publication to the IUCN (for those concerning management of tropical wetlands), a specialised international journal (*Wetland Ecology and Management*), and an ecological journal (*Bulletin d'Ecologie*):

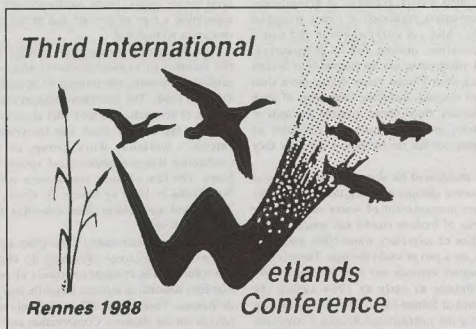
— twenty-one papers presenting results applied to management and valorisation of wetlands in tropical regions, which hold interest for developing countries, will be published by The World Conservation Union (IUCN, International Union for Conservation of Nature and Natural Resources) in 1991;

— thirty-eight papers were accepted for a first reading by « *Wetland Ecology and Management* ». The final number of papers accepted and the correction time will determine the conditions of publication;

— of twenty-five papers submitted to the « *Bulletin d'Ecologie* », thirteen were kept. Five of them deal with aquaculture and the management of exploitable fish stocks in temperate or tropical regions. Five deal with wetlands management. Three concern methods of restoration of wetlands.

The INTECOL's Fourth International Wetlands Conference will be organized in 1992 (14-18 September) at Columbus (Ohio, USA) by William J. MITSCH (The Ohio State University). The choice of Columbus was partly decided by the events planned throughout the United States for the celebration of the 500th anniversary of the discovery of the « Americas » by Christopher Columbus who, according to the history books, only reached land after crossing marismas, that is to say wetlands.

Le logotype de la Troisième Conférence Internationale sur les zones humides souligne les principales caractéristiques de ces milieux : échanges intersystèmes (milieu terrestre-milieu aquatique d'eau douce et marin), groupes-clés (macrophytes, poissons et oiseaux d'eau) et productivité élevée (système fluvial en forme de corne d'abondance).



PROSPECTS FOR INCREASING WETLAND RESOURCES BY RESTORATION AND CREATION *

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MOTS CLÉS : zones humides, création, restauration, atténuations des impacts.

KEY WORDS : wetlands, creation, restoration, mitigation.

RÉSUMÉ

L'ACCROISSEMENT DES RESSOURCES DES ZONES HUMIDES PAR LA RESTAURATION ET LA CRÉATION : UNE PROSPECTIVE.

La conférence ayant pour but « d'encourager les échanges scientifiques par la présentation de résultats de la recherche et d'expériences concrètes de gestion, en donnant une vue générale de la situation internationale », cet article entend y contribuer de trois manières. La première est de résumer les conclusions majeures des Actes de la National Wildlife Federation's 1987 Conference, « Increasing our Wetland Resources » (ZELANT & FEIERABEND, 1988). La seconde est de synthétiser ces idées en un ensemble logique de considérations sur la restauration et la création de zones humides. La troisième est de les replacer dans le contexte des efforts internationaux pour la conservation des zones humides et en évaluer la portée dans cette plus large perspective.

SUMMARY

This paper is intended to advance the Conference goal of « encouraging scientific exchanges through presentation of research results and through presentation of concrete management experience, giving an overall view of the international situation, » in 3 ways. The first is by summarizing major findings of the National Wildlife Federation's 1987 Conference Proceedings, « Increasing Our Wetland Resources » (Zelant and Feierabend 1988). The second is by synthesizing these findings into a logical statement on wetlands restoration and creation for consideration by the Congress participants. The third is by placing the issue of wetlands restoration and creation into the context of international wetlands conservation efforts and evaluating its merits from this broader perspective.

INTRODUCTION

A WIDENING CIRCLE

One of the most formative periods of man's recent history was the Renaissance. It was a time when the citizen's view of the world -including its scientific element- underwent total transformation. Intellectual barriers were broken and knowledge and enlightenment flowed into ever-widening circles. The winds of scientific change blowing during the 16th Century ultimately would influence modern environmental policy and thought.

The concept of a widening circle has merit today, as it did when first described in the 1500's, and it applies especially well to wetlands. For centuries, the wet areas of our world were regarded as nothing more than wastelands, foul-smelling tracts that harbored disease and pestilence and that were impediments to growth and progress. As a result, they became repositories for our refuse and

hazardous waste, sites for commercial and residential development, and ready targets for agricultural drainage. In recent times, however, we have come to understand that wetlands provide a number of important ecological and economic services. As this circle of enlightenment of wetlands widens, our role toward these special areas will increasingly tilt away from destroyer toward that of conservator. Much like the land ethic American author-conservationist Aldo Leopold so vigorously espoused in the 1930's, we must now become stewards of our wetlands and begin to widen the circle.

Two centuries after commencement of the Renaissance, historians write, European man arrived on the shores of what is now the United States. He brought with him dreams of a life free from religious persecution,

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hopes of independence and new beginnings, and, an insatiable appetite for food, fiber and shelter. With resolve and determination, American pioneers tamed the uncharted countryside, extracted its wealth and riches, stretched ribbons of steel and telegraph cable from Atlantic to Pacific, and enjoyed a quality of life never imagined possible. The belief that America's natural renewable resources could never be depleted was reinforced with each passing generation. Finally, in the early 1970's as the stark realization struck that, indeed, our Nation's resources were finite, words such as « conservation » and « stewardship » were dusted off and we plunged headlong into what is now termed « The Environmental Era. »

As an American citizen, I am the proud inheritor of the dreams harbored and so richly deserved by those who have gone before me. Sadly, I also am the inheritor of the environmental debt now due for fulfilling the dreams, a part of which was the destruction of more than half of the wetlands in the United States. In the brief 200-year history of the United States, my Nation has reduced its wetland base from 215 million acres to less than 95 million acres and authorities inform us that wetlands in the U.S. continue to be destroyed at an annual rate of 300,000 to 500,000 acres (FRAYER *et al.* 1983). Unless these losses are slowed, stopped, and reversed, the entire wetland base of the United States will be eliminated in another 200 years.

A SUMMARY OF THE MAJOR FINDINGS OF THE CONFERENCE, « INCREASING OUR WETLAND RESOURCES »

What follows is a summary of the major results of the 1987 Conference, « Increasing Our Wetland Resources. » This was an international conference hosted by the National Wildlife Federation's Corporate Conservation Council in Washington, D.C. in October 1987. The Conference objective was to evaluate scientific « state-of-the-art » knowledge of wetlands restoration and creation and to discuss prospects for increasing the wetlands base of the United States and the world. The Conference assembled more than 500 participants from several nations who heard presentations from academicians, policymakers, industry and conservationists, all experts and authorities on a wide range of issues concerning wetlands restoration and creation. Among the topics covered were (1) wetland loss in the United States and worldwide, (2) case histories examining current wetland management and the practicality of creating and restoring wetlands, (3) how to generate local, governmental, organizational and financial support for wetlands restoration and creation projects, (4) legislative, public and private actions which can be pursued to encourage

rebuilding of our diminished and degraded wetland inventory and (5) future needs.

As might be predicted, the views expressed by the participants on our ability to restore and create wetlands were as diverse and far-ranging as the conferees themselves. Despite this, 3 major themes recurred throughout the Conference and on which there appeared to have been consensus.

First, the public is becoming increasingly less tolerant of knowing and deliberate alteration and loss of wetlands. The time is now passed that the general public will continue condoning loss of wetlands as the status quo. This view was expressed directly and indirectly in papers presented by government officials (JENSEN 1988), industry representatives (FISCHEL 1988), consultants (HEY 1988), legislators (KASTEN 1988), academicians (ZEDLER 1988), and environmentalists (O'DONNELL 1988). Of interest is that the scientific community, as much as anyone else, is responsible for fueling this « age of enlightenment » in the public sector. As researchers continue ascribing attributes of wetlands benefitting society - both those economical and those ecological - with ever-increasing sophistication, the public response is one of heightened sensitivity to wetland protection and greater mobilization to seeing more done to protect and to conserve these areas. Moreover, we are witnessing what I believe to be only the beginning of this « Wetlands Renaissance » and that, as public and private institutions increase their efforts to educate the public as to wetlands and the many benefits they provide society, these sentiments will amplify and intensify.

Second, although much has been learned in recent years and our knowledge augmented considerably, « state-of-the-art » scientific understanding of wetlands restoration and creation is limited, inadequate, and an unreliable predictor for success. The divergence of opinion among Conference participants on this point was greater than that of the importance of wetlands discussed above, but is one on which there was general convergence. For example, while many participants spoke eloquently of successes they had made in restoring and creating wetlands (BASKETT 1988, BRUNORI 1988, RICHARDSON 1988), they also recognized that failed projects - either partially or completely - are not uncommon. In fact, one industry representative concluded that, « *there is still much uncertainty over the ability of a restored or created wetland to function as 'natural' marsh. The lack of sufficient scientific data on the success of these projects has lead many wetland scientists and regulators to conclude that, at the present time, wetland restoration and creation should not be routinely used as a means of mitigating for the adverse impacts of development activities* » (FISCHEL 1988 : 128).

The opposite end of this philosophical spectrum is exceedingly skeptical of our ability to create and restore

wetlands and has challenged the scientific basis for claimed successes. Many participants (O'DONNELL 1988, ZEDLER 1988) remain unconvinced we can consistently create and restore wetlands that will persist and provide the functions of natural systems they are intended to replace. One author, who has described state-of-the-art wetlands restoration and creation as nothing more than « aquatic gardening » (LARSON 1988 : 73) concludes that, « *Wetland creation has little scientific foundation on which to base confidence in replacement of lost functions...[and]... The success of wetland restoration is not well documented in the scientific literature* » (LARSON 1988 : 77).

The one point clear from both sides of the discussion is that there is need for much better scientific information regarding wetlands restoration and creation, something that will take years, perhaps decades, to generate. It is apparent, therefore, that the conference participants consider the science of wetland restoration and creation to be « only in its infancy » (MALBY 1988 : 5). It is an area of scientific pursuit and investigation demanding a much more vigorous approach and reliable database before strong and unqualified statements can be made regarding man's ability to successfully restore and create wetlands.

Third, although the cost to restore wetlands is generally less than the cost to create wetlands, both are extremely expensive activities and oftentimes cost-prohibitive. There was consensus among conference participants that the cost to restore and create wetlands can be significant. For example, project costs for restoration cited by various speakers ranged from a low of \$ 140/ha (MADSON 1988) to a high of \$ 100,000/ha (METZ 1988). In sharp contrast, costs cited to create wetlands ranged from a low of \$ 5,000/ha (RICHARDSON 1988) to a high of \$ 1.5 million/ha for what the author describes as « *the extreme response of physically transplanting wetlands* » (MALBY 1988 : 11). Several authors also reported on creating wetlands for wastewater treatment and cited figures for these projects to average about \$ 400,000/ha (STEINER *et al.* 1988). These estimates clearly indicate that wetlands creation and restoration can be extremely expensive, even when the project scale is on the order of as few as 5 or 10 hectares. The mere fiscal support needed for these, and even larger scale projects, seems to constrain this technology from gaining broad nearterm applicability, in North America or elsewhere.

THE COMMON THREADS

At first glance it appears these 3 points bear little relationship to one another. Closer inspection, however, reveals they are closely linked and -when viewed cumulatively- afford considerable insight into the discussion of wetlands restoration and creation.

Specifically, combining : (1) public resistance to continued alteration and loss of wetlands ; with (2) an inadequate scientific base for wetlands restoration and creation ; with (3) the high financial cost of creating and restoring wetlands, then one must conclude that policy for wetlands should be driven by avoidance rather than by creation and restoration. Said differently, the primary emphasis for wetlands should be placed on the protection and conservation of existing systems rather than on the restoration and creation of new ones. Certainly, it is naive to suggest that a public demanding such policy would also prohibit any alteration or loss of wetlands and not recognize the need to periodically impact these systems. A wetlands policy must reflect these concerns, but it must also provide consistency and emphatically place wetlands and the myriad public benefits they provide ahead of private and personal gain to be derived from their alteration. It is simply poor policy to continue sacrificing the ecological and economic benefits provided to the public by wetlands, many which -once lost- may never be regained. Therefore, we should seek to establish policy that emphasizes -truly emphasizes- avoidance of wetlands and that looks to restoration and creation in only the extreme and exceptional instance.

At this juncture, 2 options are available. The first is to emphasize protection and conservation of wetlands and to apply restoration and creation judiciously and only as a last resort. The second is to accept the status quo of continued alteration and loss of wetlands and to rely on restoration and creation to compensate for these losses. In my view, the latter stands logic on its head, is vulnerable to attack both scientifically and economically, and is counter to public interest. Only does a comprehensive and aggressive policy of wetlands protection and conservation stand a chance to slow, perhaps stop, continued erosion of the global wetlands inventory.

INTERNATIONAL IMPLICATIONS FOR WETLANDS RESTORATION AND CREATION

Much of what precedes draws on the North American perspective and, on a global basis, derives from what may be described as parochial experience. Nonetheless, these findings have applicability to countries and economies beyond the borders of my Nation. First, even countries whose economies can afford wetlands restoration and creation should question whether such technological approaches are the most appropriate uses of limited resources. For instance, might those monies dedicated to creating wetlands be better invested in acquisition, public education programs, or research ? Buying into the restoration and creation philosophy without adequate forethought can be capitol-intense, risky, and seated in poor policy.

Second, and a point made emphatically during the NWF Conference, is that wetlands restoration and creation programs have little, if any, relevance to the developing world (DUGAN 1988). Specifically, countries whose annual operating budgets are only in the hundreds of millions of dollars can ill-afford wetland restoration and creation projects costing millions of dollars. These nations simply lack the fiscal resources - not to mention the desire or motivation - to undertake such projects, and are the ones that can least afford to repeat mistakes made by the United States and others. Turning the wetlands clock back in developing nations is simply not going to happen. Instead, we should work to foster a wetland conservation philosophy in these nations, their people, their leaders, and their institutions. If the developing world and its residents are to rise above the challenges of today, then stewardship and wise utilization rather than exploitation and obliteration of wetlands must emerge because the art and the science of wetland restoration and creation will not have a place in these economies for decades to come.

CONCLUSION

The art, some say the science, of wetlands restoration and creation is an exciting and challenging area of scientific inquiry. It is a fertile field of research warranting vigorous and objective investigation. This said, it is also critical that researchers, policy makers, government institutions, industry, and others interested in wetlands fully recognize the scientific limitations and the financial obligations associated with wetlands restoration and creation. This is why our primary energy should be directed into protecting and conserving the existing wetland base rather than accepting its loss on assurances that these losses will be fully compensated for by restoration and creation. It is in the longterm interest of everyone - whatever their stake in wetlands - to avoid disposing of a heritage that took millennia to create but in a moment's time could be lost forever.

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ADEQUACY OF THE SCIENCE BASE FOR WETLAND RESTORATION AND CREATION*

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MOTS CLÉS : zone humide, création, restauration, atténuation des impacts

KEY WORDS : wetland, creation, restoration, mitigation.

RÉSUMÉ

LES BASES SCIENTIFIQUES POUR LA RESTAURATION ET LA CRÉATION DES ZONES HUMIDES.

Bien que la réussite de la restauration ou de la création d'une zone humide ait été longtemps appréciée par le développement de la végétation, il faut rappeler que l'aspect satisfaisant de la nouvelle végétation ne prouve pas que le système assure des fonctions hydrologiques et trophiques convenables. Un jardin aquatique ne remplacera jamais une zone humide naturelle.

Dans sa synthèse du National Wetland Symposium : Mitigation of Impacts and Losses, KUSLER (1986) a souligné que les suivis de sites restaurés ou créés étaient insuffisants pour autoriser des généralisations sur les conditions de réussite. Près de la moitié des projets présentés à ce Symposium n'avaient pas atteint les objectifs fixés. Souvent, les aspects hydrologiques n'avaient pas été pris en compte convenablement. Les aménageurs ne s'appuyaient guère sur des expertises scientifiques et bien peu faisaient l'effort de préciser qualitativement et quantitativement les fonctions de zones humides qu'ils avaient altérées.

KUSLER concluant également que si l'on savait recréer les conditions du contrôle des inondations, reconstituer les habitats de certaines espèces sauvages, éventuellement des fonctions relatives à la qualité de l'eau, il n'y avait en revanche qu'une faible probabilité de réussite en ce qui concerne la reconstitution des liaisons avec les eaux souterraines. Ses conclusions sur l'insuffisance de connaissances scientifiques de base rejoignent celles de différents auteurs.

SUMMARY

In the past, the creation and restoration of wetlands has dealt primarily with plant communities and certain wildlife species, particularly birds. Today there is increasing interest in the ecological functions that relate to human health, welfare and safety such as : flood control ; maintenance of water quality ; groundwater recharge ; and sustainable production of food and natural fibers. Scientists are beginning to create artificial wetlands or restore former ones in order to replace the functions lost when natural wetlands are destroyed. The science base is adequate to predict successful replacement of flood control, sediment stabilization and limited wildlife habitat functions in artificial wetlands. For most other functions, there is little to ensure that artificial wetlands be successful substitutes for natural wetlands.

INTRODUCTION

Commonly wetland ecologists have been seen to be primarily interested in conservation of plant and animal communities (HOLDGATE, 1978). As pressure increases, world-wide, to meet socio-economic needs of people by more intensive land use, ecologists are increasingly involved in other natural functions of wetlands. These include

the roles of wetlands in recharge and discharge of groundwater, flood and erosion control, water quality maintenance via sediment trapping and chemical transformation, food and fiber production, sustenance of traditional human cultures as well as food chain and habitat support for fish and wildlife.

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Many wetland areas remain in a natural state today because they have been difficult to convert to other uses or the hazards of putting them to other uses have been deemed too high risk. But modern technology has made it possible to engineer conversions of wetlands on a massive scale. In the United States wetland alteration is regulated by law and developers are required to take into account the loss of natural wetland functions in their plans. Under these conditions, developers are beginning to propose that modern technology can also be used to build a wetland that will replace the natural one lost by filling or draining.

OBJECTIVE

Ecologists are being asked whether an artificial wetland will perform the same functions as the natural wetland it replaces. LARSON (1988) reviewed efforts made by scientists in different regions of the United States to assess the scientific basis for wetland creation and restoration. This paper expands on that review.

WETLAND CREATION

The most common criterion that is used to judge whether a created wetland is a success is whether plants grow following construction. But documentation is usually anecdotal, not scientific, and rarely covers more than one or two years. An exception is the work of the U.S. Army Corps of Engineers on sites created from disposal of material dredged from rivers and harbors (NEWLING & LANDIN, 1985; CORPS OF ENGINEERS, 1987; LANDIN & SMITH, 1987). The ability to predict which species will grow is not high. Sea grasses are not likely to become established where none grew previously (FONSECA *et al.*, 1988). *Spartina*, mangroves and freshwater herbaceous communities can grow where pre-oper hydrology, topography and soils are provided, but forest floodplain communities are extremely difficult to establish (WALKER, 1986).

SHARITZ & LEE (1985) note that long term effects of water management on forested wetlands is poorly understood, but found evidence that flood events have a critical effect on seed banks. The LARSON (1988) review and BARKHOUSE (1987) note that vegetation in man-made wetlands may show a favorable response for a few years but vigor declines after 5-8 years, especially if there is no active management of hydrology. Techniques for establishing wetland plants on mine spoil sites have been compiled by BROOKS *et al.*, (1985).

Organizations that create wetlands for wildlife often conduct extensive surveys on the natural wetland before it is destroyed and on the new area to document use by spe-

cific species and they create wetlands with particular species in mind. This kind of design for specific objectives should be an integral part of wetland creation. But rarely do others who propose to create a wetland actually document the types and level of functions being provided by the wetland they wish to destroy. Yet, if that information is not presented as part of the basis for designing an artificial wetland, on what basis can a developer claim the new wetland will be an adequate functional replacement?

WETLAND RESTORATION

Restoration of degraded wetlands or drained sites that were formerly wetlands appear to hold more promise for functional success. Scientists can provide significantly more assurance that wetlands similar to the originals will become established on restoration sites. Several manuals have been developed for restoration of freshwater marsh vegetation (PIEHL, 1986) and marine coastal marshes (ZEDLER, 1982 & 1984). GRONDIN & COUILLARD (1987) have developed specific recommendations for restoring *Acer saccharinum* wetland forests in Quebec, Canada.

Restoration of former tidal and freshwater marsh communities on the Atlantic and Gulf coasts of North America has received attention in recent years. In the state of Connecticut, while creation of freshwater marshes in conjunction with road construction has gone on without evaluation for over 10 years (BUTTS, 1988), restoration of former coastal marshes by installation of culverts to re-establish tide flows appears to be more successful than creating new tidal marshes (ROZA, 1988). STEINKE (1988) has developed self-regulating tide gates that restore tidal flows and exclude peak storm surges on former tidal marshes in Connecticut.

In New Jersey, salt marsh hay communities of *Spartina*, *Juncus*, and *Distichlis* have been restored, while maintaining mosquito control, by re-establishing spring or storm tide flows on previously diked wetlands (FERRIGNO *et al.*, 1987). NEILL & TURNER (1987) have shown that marsh vegetation will return to sites where spoil dumped on a marsh is pushed back into canals no longer needed for petroleum exploration. However, little marsh vegetation returns to the filled canals since the oxidized spoil no longer fills the canal site to its former level.

The evidence for success of restoration is primarily vegetation. But where restoration is based on the original substrate and seed bank, scientists can be more confident in predicting the nature of the final plant community. Where restoration can be achieved by restoring the original hydrologic regime to a site whose substrate, topography and seed source is otherwise unaltered, the likelihood of restoration of the original functions may be possible.

SUMMARY

Although plant growth has long been the criterion by which to measure success of a created or restored wetland, it must be recalled that regardless of how attractive the new vegetation looks it is not evidence that the site is providing hydrologic and nutrient transformation functions. An aquatic garden should no longer be accepted as a replacement for a natural wetland.

In his summary of the National Wetland Symposium: Mitigation of Impacts and Losses, Kusler (1986) found that monitoring and follow up of wetland restoration and creation sites is too sparse to broadly generalize about the success of restored and created wetlands. About half of the projects reported in that Symposium failed to meet specified project goals. Hydrology was often not adequately considered in project design. Little scientific expertise was employed by the developers and few made the effort to conduct baseline studies to determine the level and kind of functions that were being performed by the natural wetlands that they had altered.

Kusler also concluded that flood control and certain wildlife habitat functions could probably be created, that there was some potential for creating functions that relate to water quality, but little likelihood of creating functions that would replicate lost groundwater recharge and discharge functions. His conclusions closely parallel those of Larson & Neill (1987) for freshwater wetlands on glaciated landscape and Larson (1988) for wetlands generally in the United States. Similarly, Garbisch (1985) notes that knowledge of restoration of marine coastal wetlands is not sufficient to form a basis for standard design criteria.

RECOMMENDATIONS

HOLDGATE (1978) has proposed five classes of activity that ecologists can contribute to protection and rehabilitation of ecosystems: conduct surveys, evaluate options, state the issues to the public, design protection or rehabilitation schemes and monitoring changes in processes. These can be applied to the scientist's role in wetland creation and restoration.

Scientists are already making major contributions to surveys of the world's wetlands. Studies of the functions of wetlands have identified the important functions of wetlands in general, but long-term site-specific functional assessment is so far inadequate.

Scientific evaluation of creation and restoration projects, as alternatives to natural wetlands, is only beginning. It will be essential that scientists be involved in weighing the options of protection, restoration and creation in wetland management schemes.

Similarly, scientists need to more clearly inform public officials that there is now little scientific basis for broad claims that modern technology can create a functional wetland and they need to know that there is a somewhat more sound scientific basis for wetland restoration.

Monitoring the performance of creation and restoration projects is almost entirely lacking. The scientific community needs to understand that the data that can be obtained from monitoring restoration and creation projects are urgently needed so that a much more sound science base is made available when future proposals are made to trade natural wetlands for artificial wetlands.

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RESTORATION OF THE « GRANDE-BRIERE MOTTIERE » MARSH OVERHAULING'S PROJECT OF THE STRETCHES OF WATER*

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MOTS CLÉS : France, marais de Grande-Brière Mottière, restauration, végétation aquatique.

KEY WORDS : France, Grande-Brière Mottière marsh, wetland overhauling, increasement, aquatic vegetation.

RÉSUMÉ

SUMMARY

REMISE EN ÉTAT DU MARAIS DE GRANDE-BRIERE MOTTIERE : PROJET DE RESTAURATION DES PIARDES.

L'exploitation de la tourbe à roseaux et Cyperacées est à l'origine des plans d'eau, appelés « piardes » et « copis », du marais de Grande-Brière Mottière (7000 hectares) (Loire-Atlantique, France). Caractérisées par une faible profondeur et l'abondance de la végétation aquatique, les piardes sont à considérer comme les mlieux les plus importants du marais sur le plan de la productivité biologique. Depuis plusieurs décennies, le déclin des activités traditionnelles a conduit à une réduction considérable de la surface en eau libre, par ensablement et progression des roselières. Le projet de restauration des plans d'eau concerne 500 ha et nécessite l'extraction de plusieurs millions de m³ de vase organique et végétaux en place (roseaux et carex). L'étude de la répartition de la végétation aquatique et amphibie, en fonction de la topographie et des variations du niveau du plan d'eau, permet de préciser les aménagements à réaliser pour la remise en état de ces mlieux. Le coût d'une telle opération est très élevé : la démarche adoptée est de chercher à valoriser les produits extraits, afin d'amortir le coût des travaux. Un chantier expérimental en vraie grandeur, en cours de réalisation, permettra de définir les modalités d'intervention sur le marais, les coûts d'extraction des matériaux et d'en examiner les modes de valorisation.

The exploitation of reed and cyperaceae peatlands is at the origin of waterbodies called « piardes » and « copis » in the Grand-Brière Mottière marsh (7000 hectares) (Loire-Atlantique, France). Characterised by shallowness and abundant aquatic plantlife, piardes should be considered the marsh's most biologically productive environment. For the past several decades, the decline of traditional activities has lead to considerable reduction in open water surfaces by silting and the spread of reedbeds. The restoration project concerns 500 ha and calls for the removal of several million m³ of organic mud and planis (reeds and Carex*). The study of the repartition of aquatic and amphibious plants, according to the topography and variations in the water level, enables us to determine what measures are necessary for the restoration of these environments. The cost of such an undertaking is very high : ways of valorising the extracted materials will be sought in order to pay for it. A life-sized experimental worksite is being made that will allow for definition of the interventions, the cost of extracting materials and ways of valorising such materials once extracted.

INTRODUCTION

The undivided Grande-Brière Mottière marsh (Loire-Atlantique - France) (7000 hectares) is the principal waterbody of a wetland complex in contact with the Loire's estuary : the Brivet Marsh (19 000 hectares).

The formation of the marsh results from the filling of a basin by clay originating in the sea, on which a layer of flat reeds (*Phragmites australis* and Cyperaceae) has grown about 1,5 to 2 metres thick.

The biological, architectural, legal and sociological singularities of the environment justified the creation, in 1970 of the Regional Natural Park of Brière (P.N.R.B.). The whole Brière, the Loire's estuary and the Lake of Grand-Lieu, are also classified in the A area of the M.A.R. project (U.I.C.N., 1965).

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TRADITIONAL EXPLOITATION

The diversity of the biotopes and the exceptional richness of the Grande Briere marsh are linked to its lagoon past, to its topography and its hydrology, characterized by an annual amplitude of the water level of about 60 to 80 centimetres, as well as to the traditional human activities of peat-cutting, horned cattle breeding and reed-cutting.

The peat used as a fuel has been the subject of important exploitation for several centuries, for example in the middle of the last century 100 000 hectoliters were unloaded every year in the harbour of Nantes. Peat was the principal natural resource of the area. This activity is at the origin of stretches of open water locally called « piardes » and « copis ». The « piardes » are characterized by shallow water, some of them dry up at the end of summer ; in winter the water is no more than one metre deep.

This helps the development of prolific aquatic vegetation (cover is 50-100 %). Several rare species (nationally or internationally) (MERIAUX, 1982) are common in the « piardes », which must be considered as the most important areas in the Grande-Brière, from a biological point of view (CONSTANT & DUPONT, 1970).

Parrallel to the peat-cutting, the organic mud piled up at the bottom of the canals was used to manure the cultivated land : 100 000 hectoliters were extracted every year in the 1880's.

At the beginning of the twentieth century, more than 3 thousand bovines and horses grazed in the marsh at the summertime. The reed *Phragmites australis* and the bulrush *Scirpus lacustris* were taken at the end of autumn or in winter to roof thatched cottages.

At the end of the nineteenth century, the industrialization of the Basse-Loire area progressively modified the life style of the human population, which became less dependent on the marsh's resources : - the exploitation of the peat and organic mud ended after the second world war - the stock of cattle and horses was no more than 200 to 300 animals at the beginning of the eighties.

EVOLUTION OF THE ENVIRONMENT AND ECOLOGICAL CONSEQUENCES

The wane of traditional activities leads to change in the area :

- canals and stretches of water silt up,
- big helophytes increase to the detriment of aquatic vegetation and wet meadows. The ecological amplitude of the reed and of the sedges *Carex elata* allows them to outcompete most of the plant communities of the Brière (ROZÉ *et al.*, 1980). Today tall helophytes cover more than 85 % of the marsh, meadows 10 % and aquatic vegetation less than 5 %.

Figure 1 shows the recession of the stretches of open water since the stopping of the peat-cutting :

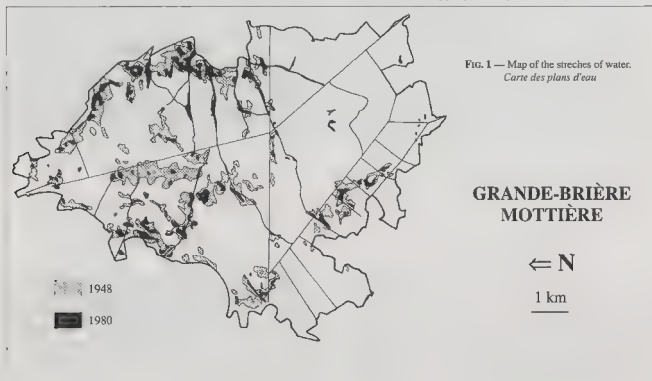


FIG. 1 — Map of the stretches of water.
Carte des plans d'eau

- 1948 : more than 700 hectares.
- 1980 : 270 hectares.

The overgrowing the stretches of water by the reed-beds is caused by the progression of the tall helophytes from the periphery to the center, or, in deeper stretches of water, by the formation of floating islets which divide and then fill up the « piardes ». The continuous extension of reed-beds, and the appearance of woodlands with willows *Salix atrocinerea* in some places, shows the natural evolution towards filling up (CONSTANT *et al.*, 1987).

The loss of biological diversity caused by the extension of the reed-beds cause the impoverishment of the ecosystem :

- the richer communities from a floral point of view (DUPONT, 1972), especially the amphibious vegetation communities, occupy smaller and smaller areas ;

- this phenomenon plays a great part in the decrease of the stock of fishes and batrachians which use the stretches of water and easily flooded meadows as a feeding area or a spawning place (BAUDOUIN-BODIN & MAILLARD, 1972),

- the expansion of reed-beds also modifies the possibilities of sheltering aquatic birds (CONSTANT *et al.*, 1988). Moreover, the abundance of birds in the reed-beds is directly connected to their proximity to the water : the further you move from the aquatic area, the poorer the vertebrate community becomes, on a qualitative as well as on a quantitative scale (CONSTANT, 1972).

THE OVERHAULING PROJECT

The syndical Committee of the Grande-Brière Mottière, manager of the undivided marsh, and the P.N.R.B. have led different actions to stop this phenomenon. These actions have permitted the overhauling of the canals, as well as of the wet meadows, and a noticeable increase of cattle breeding for the past six years (1 100 bovines and horses in 1987).

The managers endeavour to overhaul the stretches of open water.

ECOLOGICAL AND ECONOMIC APPROACH

The project, based upon the situation in 1948 (FIG. 1), corresponds to the overhauling of some 500 hectares. These works require the extraction of tall helophytes and the organic mud filling up the former water stretches. Some of the most important characteristics to consider for the biological success of the new « piardes » are topographical.

These parameters could be measured by the vegetation transects in areas still maintained which offering great biological diversity (FIG. 2) (ROLLAND, 1985). The topography is plotted in winter by measuring

water levels, the results being compared with the limnigraphic measurements on the « Ile de Fédrun ». The outlines show very slight slopes, 0.5 to 1 % over distances of 100 to 200 metres, and areas, called « buttes » (knolls), towards the middle of open water stretches.

The transects of vegetation (method of abundance/dominance coefficients (BRAUN-BLANQUET set) are realized after the retreat of the waters along the same outlines. The application of the method on seven areas, distributed throughout the marsh, allows determination of the distribution of the vegetation according to the topographic levels :

- settled aquatic vegetation : - 0.25, - 0.3 m N.G.F. (Nivellement Général de la France) to 0.25, 0.3 N.G.F., which means an amplitude of 0.5 to 0.6 m,

- amphibious vegetation : 0.25, 0.3 N.G.F. to 0.75, 0.85 N.G.F., which means an amplitude of 0.5 to 0.6 m to,

- beyond 0.75, 0.85 N.G.F. mesophile vegetation settles. These results make possible the definition of the depths of dredging, which must not be more than - 0.2 m N.G.F. so that rooted aquatic vegetation can develop. The fixed levels of extraction and the continuous limnigraphic surveys make possible the correction of the depth of the excavation according to the variation of the water level.

The results obtained regarding the vegetation corroborate those of HEDIN (1985) on use by birds. Within the framework of the development of a wildlife park in Saint-Malo-de-Guersac, this author showed the positive influence of the surface type, of the gently sloped and shallow banks of water stretches, on the numbers of Anatidae and waders.

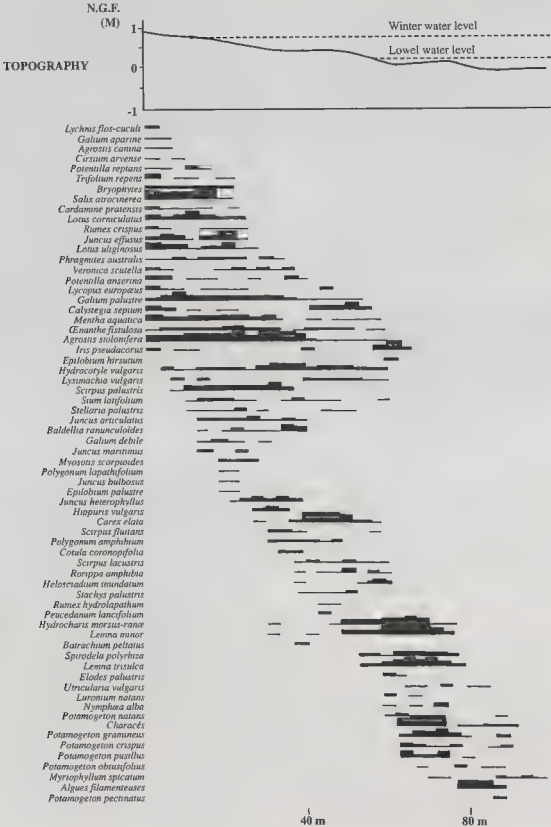
The wildlife Park's improvements, as well as some more limited works in the marshes, obviously show that colonization by settled aquatic or amphibious vegetation in reshaped areas is possible in a few years, if the gently sloped areas are well maintained. On the above mentioned bases (surface, depth, gently slopes), the project requires the extraction of three to four million cubic metres of mud and an almost equal volume of plants.

The total cost is several million francs ; and moreover the problem is how to then get rid of the plants and mud. The chosen approach is to try to use the extracted products to cover the cost of the work : hence industrial partners are associated with the operation. The richness of organic matter in the mud (higher than 70 % oven-dry weight) allows us to hope for agronomical outlets. Economically, France could benefit from the exploitation of the mud, which is an abundant and renewable resource of organic matter which France now imports.

EXPERIMENTAL WORKING SITE

Life-size tests, on one hectare began in 1988 with two companies, one specialized in dragging, the other one

FIG. 2 — Transect of vegetation.
Transect de végétation



specialized in agronomy. The tests were paid for by these two companies and the P.N.R.B.

The first stage in the tests, that is to say the extraction of muds and plants, based on the schedule of conditions specifying the depth of digging, was realized in six weeks in February and March 1988 : 7 000 cubic metres of products were extracted with an amphibious shovel (KONIJN TM) and carried away by barges to the edge of the marsh, where they were stocked in a lagoon so that they could dry out.

The assessment of this first stage will enable us to optimize the techniques according to local conditions, and to determine the costs of the extraction. The ecological monitoring of the work site also allows evaluation of the quality of the works as well as the consequences for water quality.

The second stage concerns the commercialisation of the extracted products. The first results show that organic mud, not compostable, couldn't be used as an organic improvement. On the other hand, its physical qualities, especially its porosity, seem to make it useful as raw material for artificial soils, like mould. For this, the mud would have to be mixed with peats to improve the water retention capacity. The marketing could address the general public, but also regional professionals of market-gardening of horticulture and of arboriculture.

These assumptions will be evaluated by tests of cultivation, underway. Some problems such as the commercialisation of reeds and sedges, or the salinity of the mud still need to be resolved.

CONCLUSION

The realisation of the project to restore the Grande-Brière depends on the technical and economic results obtained by the tests in process : the financial assessment of the costs of extraction and the eventual marketing of the products will make possible or not the self-financing. If it is possible, the potential market for the products will determine the annual masses to extract : the first evaluation suggests that the works could last seven to ten years, with 50-70 ha per year.

The overall assessment of these tests will be made in 1989.

The ecological restoration of the stretches of open water of the Grande-Brière represents one of the necessary improvements for the preservation and the enhancement of the biological richness of this wetland. The fast succession for several decades leading to the filling up, shows the urgency of bringing into play proper resources. The economic approach of the project is essential because of the costs involved.

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VI^e CONGRÈS EUROPÉEN D'ÉCOLOGIE

ORGANISÉ PAR LA FÉDÉRATION EUROPÉENNE D'ÉCOLOGIE
ET LA SOCIÉTÉ FRANÇAISE D'ÉCOLOGIE
MARSEILLE, 7-11 SEPTEMBRE 1992

Il s'agit du 6^e Congrès Européen d'Écologie qui est organisé pour la première fois par la Fédération Européenne d'Écologie, fondée en mars 1990 afin de promouvoir la coopération entre les écologistes européens. Le congrès comprendra, le matin, des séances plénières avec des conférenciers invités et des communications, et, l'après-midi, des sessions parallèles avec des communications orales et par affiches sur des thèmes différents.

Les thèmes des séances plénières sont :

- Impacts urbains sur les écosystèmes
- Génétique écologique et comportement
- Risques écologiques
- Bases écologiques en vue de la conservation de la biodiversité

Les thèmes envisagés pour les sessions de l'après-midi sont :

- Contraintes écologiques et stratégies des cycles de vie,
- Génétique, dynamique et modélisation des populations en habitat fragmenté
- Dynamique des écosystèmes, évolution des paysages et impact humain
- Impact de la déforestation sur les écosystèmes naturels,
- Perturbations,
- Intégration des communautés dans leur environnement physique,
- Approches théoriques de l'écologie et études de cas,
- Dynamique et hétérogénéité,
- Risques environnementaux du contrôle biologique et du génie génétique,
- Écologie microbienne,
- Bioénergie et comportements trophiques.

Toutes les suggestions concernant des thèmes supplémentaires reçues avant le **1^{er} Avril 1991** seront prises en considération. Le programme définitif dépendra du niveau d'intérêt des différents thèmes.

La langue principale du congrès sera l'anglais, mais le français pourra être accepté (en cas de traduction simultanée).

Les actes du congrès seront publiés selon les règles en vigueur dans les revues scientifiques.

Des ateliers fédérateurs sur des thèmes particuliers pourront être organisés le soir; les personnes intéressées doivent en informer le Secrétaire général de la Fédération.

La première circulaire sera distribuée à toute personne ayant manifesté un intérêt pour le congrès avant le **1^{er} Avril 1991**. Prière d'indiquer le thème qui vous intéresse et si vous prévoyez de présenter une communication orale ou par affichage.

Toute information pourra être obtenue auprès du Bureau du Congrès ou du Secrétaire des Programmes de la Fédération.

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MANAGING WETLANDS IN COASTAL LOUISIANA FOR PLANTS, WATERFOWL, FISH AND OTHER ANIMALS*

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MOTS-CLÉS : Louisiane, zones humides, aménagement, hydrologie.

RÉSUMÉ

L'AMÉNAGEMENT DES ZONES HUMIDES CÔTIÈRES DE LOUISIANE.

L'aménagement des zones humides des côtes de Louisiane est confronté à une grave perte en superficie, de l'ordre de 0,8% par an depuis 1955. Si certains travaux hydrologiques ont eu pour finalité de favoriser diverses composantes de la faune, il faut surtout prendre conscience de l'impact cumulatif des canaux et levées de terre créés pour satisfaire les besoins des industries du pétrole et du gaz naturel. Les régimes hydrauliques, les taux de sédimentation et la chimie des sols sont modifiées, avec diverses conséquences sur les populations végétales et animales. Renverser la tendance et éviter la perte de zones humides suppose une nouvelle conception, à l'échelle régionale, de l'utilisation des canaux et levées de terre.

KEY-WORDS : Louisiana, wetlands, management, hydrology.

SUMMARY

Management of the coastal wetlands of Louisiana is faced with significant loss rates approaching 0.8 %/year since 1955. If certain hydraulic works have favored various elements of wildlife, we mustn't forget the cumulative impact of the canals and levees built to meet the needs of the large oil and natural gas companies. Hydrosystems, sedimentation rates and soil chemistry are modified with various consequences on plant and animal populations. Reversing and avoiding further loss of wetlands requires a new local conception of using canals and levees.

INTRODUCTION

Louisiana's coastal wetlands comprise 41 % of the U.S. total, and are a State, national, and international resource. They are the source of more than 25 % of the US fisheries landings, home for the nation's largest concentration of overwintering waterfowl, and yield the largest fur harvest of all the U.S. states. When Louisiana became part of the United States after the War of 1812 these wetlands were already populated by hunters, trappers and fishermen who occasionally modified wetlands with navigation trails. A few farmers also tried to reclaim wetlands using levees. With passage of the Federal Swamp Lands Acts in 1859, 1860, ownership passed from Federal to State and then to private hands. More and larger wetland management followed, either directly or indirectly, either passively

or actively. At least 43 large scale agricultural impoundments were built by 1915 ; most of them failed (TURNER & NEILL, 1984). Serious cypress logging began at the beginning of this century and aquaculture ponds developed as early as the 1950s. The Mississippi River was effectively walled in with levees from Vicksburg to almost the Gulf of Mexico after unexpectedly high floods in the 1920s. However, the most intensive and extensive modification of wetlands results from the growth of canals dredged since the 1930s when offshore and onshore oil.

Canals in coastal Louisiana are built with various dredging methods to assist navigation, belowground mineral recovery, pipeline construction and trapping. Most canals are constructed to service the offshore and onshore oil

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and gas industry which largely developed after 1940. Each oil and gas field in the coastal wetlands has numerous canals and spoil banks. Canals are dug to float in drilling equipment, and the spoil banks are the residual dredging materials placed on either side of the canal in a continuous line. Oil and gas annual production rates peaked about 10 years ago and has since declined. Consequently, fewer canals have been built in recent years although the cumulative total canal area created continues to climb. Presently, the surface area of canals is equivalent to 2.3 % of the present wetland area (Table I). Every hydrologic unit has a significant area of canals that has increased greatly in the last 25 years. Overall, the total area of spoil bank levees plus canal surface is about 9 % of the present wetland area which is equal to the natural channel density in a undisturbed marsh (about 8 % to 10 %); therefore, a major hydrologic adjustment has taken place. The annual enlargement of five major canals range from 2 % to 14.8 % or a doubling rate from about 5 to 35 years or more than the area of new canals added each year. There is hardly a place in the Louisiana coastal zone where canals and their impacts are absent.

For 7 000 years there has been net land gain along this coast together with periods and localized instances of land loss; from 1955-78 it was 0.8 % annually for the whole coastal zone (Table I). Some segments of the Louisiana coast are eroding faster than others and barrier island retreat and erosion are severe. Although there is land gain in some areas, overall the loss rates are very significant in all of the hydrologic units. The highest rates of change are within the saline and brackish marshes in the deltaic plain and within the brackish and fresh marshes of the chenier plain to the west.

TABLE I — Area (ha) by habitat type in Louisiana's coastal zone and the change in areal extent at each habitat type from 1955/56-1978 (from BAUMANN & TURNER, 1988)

Surface (ha) par type de milieu dans la zone côtière de Louisiane et changements d'étendue entre 1955/56 et 1978 (d'après BAUMANN & TURNER, 1988)

Habitat Description	Area (hectares)		Change 1955/56-1978
	1955/56	1978	
Marsh	1 265 004	1 009 320	-255 684
Swamp	209 808	177 078	-32 730
Forest/Upland	48 519	57 550	+9 032
Aquatic Grass Bed/Mudflat	6 545	26 788	+20 243
Canal and Spoil	34 071	80 426	+46 355
Open Water	1 975 399	2 162 776	+187 377
Urban/Agriculture	184 298	211 848	+27 550
Beaches and Dunes	4 758	3 081	-1 677
	3 728 402	3 728 867	

Management of the remaining coastal wetlands is also intimately influenced by the hydrologic regime and there is a possibility for reversing habitat changes, even wetland to water conversions, in some areas. Existing management measures include annually - or seasonally - adjusted water level regulation using weirs, flap gates, earthen plug, and levees (COWAN *et al.*, 1988) and restoration (NEILL & TURNER, 1987). Marshes are often burned to alter vegetation characteristics, and soil wetness is an important variable affecting aboveground plant flammability and belowground peat combustion. Several extensive water level management schemes are employed, with mixed success, on some wildlife preserves, but are generally much too expensive for use on the vast.

There are, however, no experimental studies of how different management measures, proposed for different ends and affecting common resources, affect the long-term stability of the marsh ecosystem. When management has been intentional, it has been a « fish, fowl or fur » management with faunal elements. This is not a criticism of the present management; it is a conclusion of what we do not know and need to know as wetland losses continue and affect management plans designed for other reasons. For example, weirs are commonly used to promote open water expansion and to attract overwintering waterfowl. Weirs are apparently not, however, having the desired effect of conserving wetlands providing the very habitat supporting the long-term needs of fish, fur or waterfowl (Table II). In general, our assumptions of what is best to do are supported by only unexamined hypotheses. This is a dangerous situation since the desire to do « something » is strong when the problem (land loss, in this case) is most severe; massive restoration efforts may only exacerbate the biological and sociological situation if the presumed cure is worse than the disease.

MANAGING CANALS AND SPOIL BANKS

A recently completed \$ US 1.5 million study by 24 Louisiana research scientists concluded that canals and spoil banks are the most likely cause of at least 30-59 % of Louisiana's coastal wetland losses from 1955-1978 (TURNER & CAHOON, 1987). Sixteen percent of these wetland losses are the direct impacts of dredging wetlands into open water and spoil bank; at least 14-43 % of these wetland losses were from the indirect impacts of spoil banks and canals on wetlands. Another 13 % of wetland losses were due to agricultural and urban expansion into wetlands. Canals and spoil banks, therefore, deserve special attention by managers.

The causal mechanisms for the indirect impacts of even individual canals and spoil banks are : (1) lower sedimentation behind spoil banks in any marsh type because

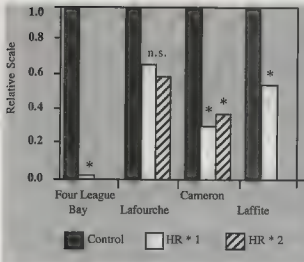


FIG. 1 — Vertical accretion rates in four areas hydrologically restricted by single spoil banks in four different regions (HR 1 and HR 2) compared to control sites nearby. Data were normalized to the control site values (100%). A * by the bar indicates a statistically significant difference between the hydrologically-restricted site and the control site. Adapted from CAHOON & TURNER, in press.

Taux d'accrétion verticale dans quatre zones à hydrodynamisme modifié par une levée de terre dans différentes régions (HR 1 et HR2), comparés aux taux mesurés dans des sites témoins voisins. Données normalisées par rapport aux valeurs (100 %) des sites témoins. Un signe* indique une différence significative entre le site modifié et le site témoin

of the reduced frequency and depth of tidal inundation (Fig. 1). These sedimentation reductions are many times greater than sea level rise; (2) wetland drying cycles may be increased, even in semi-impounded marshes resulting in lengthened drying periods for soil oxidation to take place and subsequent soil shrinkage (Table III); (3) individual wetland flooding events may also lengthen behind spoil banks (Table III). Presumably the latter is a consequence of water being trapped behind the spoil bank once water enters the marsh overland during very high tides. When marsh flooding increases enough to seriously waterlog soils then soil chemistry changes, and plants may become stressed. Plant production is related to soil flooding and we are now beginning to quantify the relationships in a meaningful way. Plant production is usually higher when flooding is reduced and lower when flooding is increased (Fig. 2), but the effect may vary, depending on the species and salinity. Plants contribute to marsh stability through sediment trapping, erosion resistance, and organic contributions to soils. These wetland soils must accumulate enough material vertically to compensate for the relative rise in water level from rising sea level, sediment compaction and a geosynclinal tilt in the basement material. The cumulative result may be a relative increase in water level leading to lower plant production and further stress to the

TABLE II — Effects of weirs on wetland ecosystems in coastal Louisiana (adapted from TURNER *et al.*, 1988, in press and HERKE & BARTON, in press).

Effets des barrages sur les zones humides des côtes de Louisiane (adapté de TURNER *et al.*, 1988, sous presse, et de HERKE & BARTON, sous presse)

Parameter	Higher	No change	Lower
Water Salinity	changes less than +/- 2 ppt		
Water Oxygen	—	X	—
Turbidity	—	X	X
Soils			
Eh	—	—	X
pH	—	—	X
salinity	X	X	—
organic content	—	X	—
Pond Siltation Rate	—	—	X
Vegetation Coverage			
in Ponds	X	X	—
in Marsh	—	X	—
Waterfowl density			
summer	—	X	—
fall	—	X	—
winter	X	—	—
spring	—	X	—
Annual average	—	X	—
Non-game birds density			
summer	—	X	—
fall	—	X	—
winter	X	—	—
spring	—	X	—
Annual average	—	X	—
Mammal density			
muskrat	—	X	—
nutria	—	X	—
rabbits	—	X	—
small mammals	—	X	—
Hunter usage	—	X	—
Fish/Invertebrates	—	—	X

TABLE III — Changes in hydrologic regime of a salt marsh unintentionally semi-impounded by spoil banks (from SWENSON & TURNER, 1987).

Modifications du régime hydrobiologique d'un marais littoral à demi tassé par l'installation de levées de terre

	Control	Semi-Impounded
Flooding		
number of events	12.9	4.5
event length (hours)	29.7	149.9
Drying		
number of events	11.6	4.00
event length (hours)	31.2	53.9
Mean Water Level (cm)	1.71	3.99
Volume Exchange (m^3/m^3 marsh surface)		
aboveground	0.15	0.06
belowground	0.09	0.04

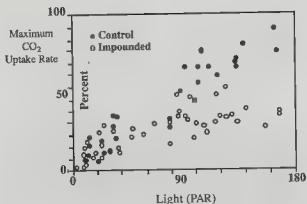


FIG. 2 — An example of the relative photosynthesis rate for *Spartina alterniflora* (April, 1987) in control and hydrologically manipulated experimental wetlands. Adapted from TURNER (1988, *in press*).

Un exemple du taux de photosynthèse relative de *Spartina alterniflora* (avril 1987) dans des zones humides témoins et à fonctionnement hydraulique expérimentalement modifié. Adapté de Turner (1988, *sous presse*).

point where plant die-back occurs. In addition, water movement belowground is decreased because of the reduced cross-sectional area and increased density of material beneath the levee. The combined effects of sediment deprivation, increased marsh drying and lengthened soil flooding result in a hostile soil environment for plants and a shortfall in the vertical accumulation of soils (needed to balance the effects of a rising sea level and a sinking land). Further small ponds are likely to become larger due to the physics of scouring under light winds in shallow ponds. One consequence of these causal mechanisms is the strong direct relationship between marsh losses and canal density.

MANAGEMENT OPTIONS

1. Reduce the number and area of old and new canals and spoil banks through, for example permitting opportunities (permit denial or modification drilling several wells from one location (directional drilling), filling the canal in upon abandonment (backfilling), and spray disposal of newly dredged materials. Mitigation for new activities may include altering previously permitted spoil banks. Maintenance dredging should not normally reconstruct spoil banks.

2. Utilize canals and spoil banks to divert water into wetland restoration areas. Innovative use of canals may be a

cheap alternative/supplement to other wetland restoration projects. Examples include the man-made levee breaches at the Mississippi River delta passes where some dead end canals leading off major tributaries were reopened.

3. Establish a regional canal and spoil bank management program to develop best management practices for spoil banks. The thousands of miles of existing and planned spoil banks and canals can be best managed with documentation of both the utility and the futility of managing the variety of spoil banks (age, size, material, alignment and location). A regional pilot program on spoil bank management, principally removal, can help forestall future losses and will help in wetland restoration.

ACKNOWLEDGMENTS : This contribution was prepared on the basis of support from the Louisiana Sea Grant Program.

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THE BAY OF SOMME (FRANCE) : A KEY-LITTORAL ZONE TO THE ENGLISH CHANNEL*

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MOTS CLÉS : Baie de Somme, Manche, peuplements macro-benthiques, perturbations, qualité biologique, ressources.

KEY WORDS : Bay of Somme, English Channel, macro-benthic fauna, disturbances, biological quality, resources.

RÉSUMÉ

LA BAIE DE SOMME (FRANCE) : UNE ZONE LITTORALE ESSENTIELLE DE LA MANCHE.

Dans cet article, les auteurs se sont attachés à montrer l'apport des recherches actuellement menées sur le littoral picard, et plus précisément en Baie de Somme, dans une perspective de valorisation des ressources naturelles de cet écosystème, exemple-type d'estuaire macrotidal.

A la lumière des travaux récents, l'originalité du site est soulignée (géomorphologie, hydrodynamisme et sédimentologie, flore halophile, peuplements macro-benthiques) avant d'exposer les grands axes de recherche : évolution biosédimentaire, impact des diverses perturbations, notion de capacité de charge, qualité physico-chimique des eaux.

Il en découle des perspectives d'aménagements, conséquences d'une réflexion en vue d'une gestion intégrée du milieu : évaluation des stocks exploitables, qualité biologique, valorisation des ressources.

SUMMARY

In this paper, the authors pay particular attention to research work on the littoral of Picardy, especially on the Bay of Somme, carried out in the prospect of ensuring the sustainable development of the natural resources of this ecosystem, a typical macrotidal estuary. From recent works, special features of the estuary are pointed out (geomorphology, hydrodynamism and sedimentology, flora, macrobenthic fauna) and the main research topics are sketched : biosedimentary evolution, trophic capacity, impact of varied disturbances.

Plans for management follow and are the consequence of further consideration on land-use : commercial stocks assessment, biological quality, development of aquaculture.

INTRODUCTION

The Bay of Somme (50° 14'N - 1° 33'E) is situated on the North Western French coast (Picardy Region). It is a large estuarine macrotidal ecosystem (70 km² of intertidal area) which is the second in area after the Mont-Saint-Michel Bay (360 km²) along the whole French coast of the Channel (figure 1).

In fact, it is made up from two jointed estuaries, the main one being the Somme which is characterized by a strong hydrodynamical process but low fresh water input (40 m³/s). Therefore, with spring-tides reaching a height of 9 m, the marine influence plays a leading part and salinity on sand- and mud-flats never drops under 25 ‰ at high tide.

Few scientific studies were carried out before 1978 (DUPONT, 1981). Then the Groupe d'Étude des

Milieux Estuariens et Littoraux (G.E.M.E.L.) perfected a general methodology of study of macrotidal estuaries (SYLVAND *et al.*, 1987; DUCROTOY *et al.*, 1988), and research work on communities (SIMON *et al.*, 1981) and environment (DUPONT, 1983) began. Application of these fundamental studies pointed out disturbances in the ecosystem through population dynamics of macrobenthic in-fauna (DESPREZ *et al.*, 1987 b) and assessment of habitat quality (WILSON *et al.*, 1987).

Part of this work was carried out in the framework of the COST 647 (European Communities Commission) and of the Programme National pour le Déterminisme du Recrutement (PNDR). Since 1985, this research was applied in a joint program between the IFREMER and the Picardy Region.

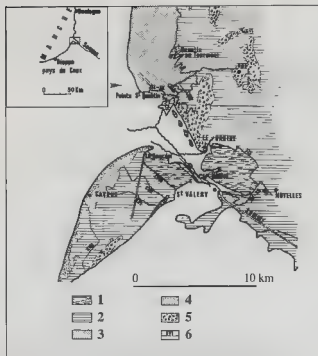


Fig. 1 — Location and geographical background of the Bay of Somme.

- (1) Salt-marshes (4) Pebble shore bars
(2) Inner marshes (5) Ancient pebble shore-bars
(3) Dunes (6) Dykes and building century

Localisation et contexte géographique de la Baie de Somme

- (1) Schorres (4) Cordon de galets
(2) Marais (5) Anciens cordons littoraux
(3) Dunes (6) Digue et siècle de construction

INTERTIDAL COMMUNITIES

More than 100 species of macrobenthic animals are found on the littoral of Picardy, but the species-richness of the infauna of mud-flats is low with 22 species (DUCROTOY *et al.*, 1986). However, estuarine benthic assemblages (deduced through factorial analysis) give rise to a high biomass (mean biomass = 27.5 g. m⁻² A.D.W., maximum biomass = 45 g. m⁻² A.D.W., DUCROTOY, 1984), an important part of which is due to molluscs such as the edible cockle *Cerastoderma edule*. The standing crop can be very high even if compared to well-known sites as the Wadden Sea (BEUKEMA, 1979, 1981) and bivalves production by local fisheries usually over-average 60% of French national landings of cockles.

Mytiliculture is very successful in the outer parts of the estuary and new aquaculture techniques could be developed in the near future.

The upper reaches of the Bay of Somme are colonized by halophile plants and salt marshes covering 12 km² (i.e. 1/6 of the bay area). The invertebrate biomass is low (0.5 to 0.7 g. m⁻² A.D.W.) due to communities where Insects and Arachnides are dominant. Plants are not consumed by

these animals but are exported towards mud-flats and the open-marine systems where they constitute an important food source (detritus and associated bacteria) for lower organisms.

Thanks to this input of organic matter (tripton), fishing in the neighbouring waters of the estuary is prosperous and hundreds of tonnes of Shrimps (*Crangon crangon*) and fish (mainly flat fishes like *Solea solea*, *Pleuronectes platessa*...) are landed every year in the Bay of Somme harbours.

Rich bird-populations use intertidal mud-flats and salt-marshes : 57 species are found throughout the year on the flats out of the 307 species known to frequent the Picardy coast (COMMECY & SUEUR, 1983). Three main groups of birds are characteristic of the estuarine flats : Anatidae (2 species), Laridae (8) and Waders (47). Even if the last group is the most diversified and plays an important part in feeding on invertebrates (TRIPLET, 1984), birds as the Herring Gull (*Larus argentatus*) and the Common Gull (*Larus canus*) are very numerous and have recently had a heavy impact on an impoverished stock of bivalves, especially on young cockles (CAUDRON *et al.*, 1983).

The Somme estuary is also an important area in Europe for migrants, Black (*Gavia arctica*) and Red-throated (*Gavia stellata*). Divers are plentiful on the sea along with Scoter (*Melanitta nigra*). Brent geese (*Brenta bernicla*) pass through as do Whooper Swans (*Cygnus cygnus*) and Black (*Limosa limosa*) and Bar-tailed (*Limosa lapponica*) Godwits form very large flocks. Breeding birds are rare because of shooting pressure, but to avoid destruction of bird populations by hunting, a reserve of 2300 ha was created in the outer parts of the bay. In the adjacent Parc Ornithologique du Marquenterre, several interesting species such as the Avocet (*Recurvirostra avosetta*) breed (SUEUR, 1985).

DISTURBANCES

The Bay of Somme has been largely reduced in size throughout the last 3 centuries from more than 500 km² of intertidal sands, and muds (figure 2). The building of dykes accelerated the natural evolution of the estuary due to the flandrian transgression, bringing in more and more material. These marine sediments accumulate in front of the bay to form a sedimentary prism. The building of two nuclear power stations and new harbouring facilities in 1975-1985 along the Pays de Caux coast (Normandie) caused an extra input of very fine and grosser particles which were trapped and deposited either on the flats where they enabled plants like *Spartina sp.* to settle (GEHU *et al.*, 1976), or where they constituted hydraulic sand dunes (DUPONT & LAFITE, 1985) in the center of the estuary.

The consequence was a rapid reduction in size of the area (figure 3) colonized by the estuarine benthic communities (DUCROTOY *et al.*, 1985; DESPREZ *et al.*, 1986).

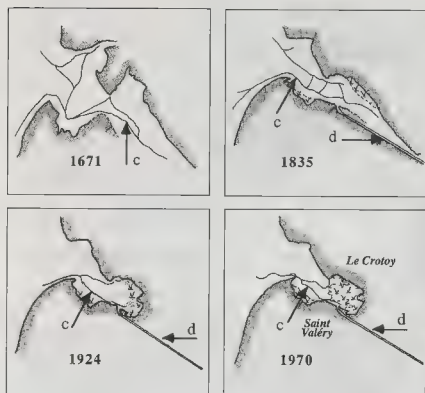


FIG. 2 — Morphological evolution of the Somme estuary during the last 3 centuries (C = Channel ; D = Dyke).

Évolution morphologique de l'estuaire de la Somme pendant les trois derniers siècles

The progression of the salt-marsh plants is linked to the important input of marine particles but it is also facilitated by the pollution of dissolved nutrients coming from the river system. Nitrates, which are present in the Somme waters up to 600 mg/l, are the most acute problem.

Recent algal (*Ulva lactuca*, *Enteromorpha* sp.) and phytoplanktonic (*Noctiluca* sp, *Phaeocystis* sp) blooms are linked to these high concentrations (GROSSEL, 1986) and several species of bivalves have suffered from severe oxygen depletion these last years ; high mortality of Cockles (*Cerastoderma edule*) and proliferation of the opportunistic polychaetes *Pygospio elegans* (figure 4) (DUPONT, 1975) throughout the whole bay, are the main examples of this eutrophication.

In these enriched waters, bacteria multiply and pathogenic organisms are currently being detected. Estuarine waters are declared unsanitary and fish-products must be purified before they are put on the market.

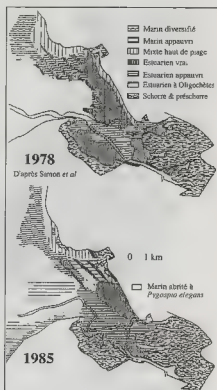


FIG. 3 — Spatial evolution of intertidal benthic communities in the Bay of Somme from 1978 to 1985

Évolution spatiale des communautés benthiques intertidales dans la Baie de la Somme de 1978 à 1985

WILSON *et al.* (1987) showed that other types of chemical pollution occur, mainly from heavy metals (cadmium, nickel, zinc and chromium), hydrocarbons and polychlorobipheniles.

MAIN RESEARCH TOPICS AND CONTRIBUTION TO ENVIRONMENT MONITORING

The drop in numbers of Cockles (*Cerastoderma*) from the Bay of Somme called for investigation of the environmental factors responsible for the decrease in bivalve populations (DUCROTOY et DESPREZ, 1986). This research was begun by GEMEL as part of a contract between the Institut de Recherche pour l'Exploitation de la Mer and the Region of Picardy (DESPREZ *et al.*, 1987 a).

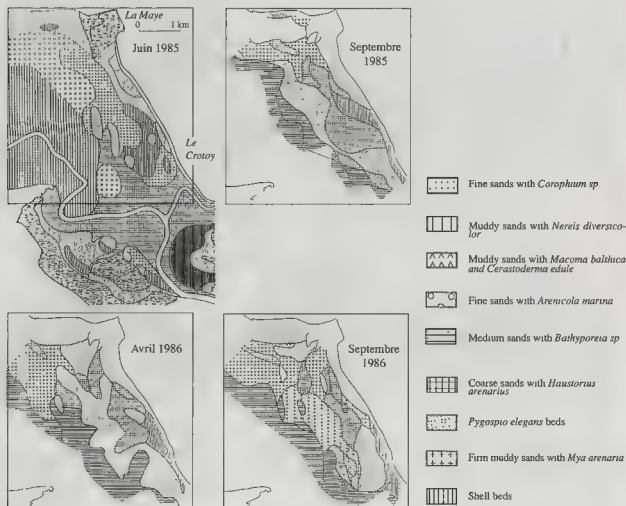


FIG. 4 — Illustration of the changes of bio-facies in the Bay of Somme during a fifteen months survey :
Illustration des changements des bio-faciés dans la baie de Somme au cours d'une période de 15 mois.

• A biosedimentary approach was essential for pointing out the main mechanisms of cockle population drop. The methodology relies on the survey of the spatio-temporal changes of biofacies.

Population mapping is based on a stratified random sampling method leading to a « zoneography » after reference to satellite and aerial photographs.

The different maps (figure 4) show the rapid changes in the ecosystem and the resulting consequences; two antagonistic phenomena are in balance and lead to a reduction of the estuarine community area :

- salt-marshes advance,
- marine sand input by tidal currents.

• This global approach has been achieved in assessing the biological quality of the estuary. Two indices (B.Q.I.,

Biological Quality Index and P.L.I., Pollution Load Index) of estuarine quality have been developed (JEFFREY *et al.*, 1985) to facilitate intercomparison of estuarine ecosystems.

In the Somme, these indices are higher than in the more polluted Seine estuary (WILSON *et al.*, 1987) and reflect mainly the intensity of hydrodynamical factors affecting benthic assemblages (I.Q.B.= 5,9) whose changes are accentuated by human activities (I.C.P.= 3,37).

• The second organization level deals with populations. Several species were selected : these species are permanent and numerous enough to integrate the environmental parameters evolution through their numbers. The distinction between « key-species » and « target-species » is based on their sensitivity to local disturbances. The res-

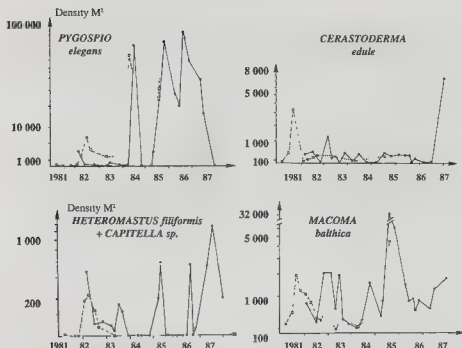


FIG. 5 — Evolution of the densities (numbers.m⁻²) of four macrobenthic species in the Bay of Somme between 1981 and 1987.

An overcrowding of the annelid *Pygospio elegans* occurred during the cockle (*Cerastoderma edule*) production crisis (1984-1986), followed by its rapid and complete collapse in 1987, during the come back of the bivalve.

Évolution des densités (nombres m⁻²) de quatre espèces macrobenthiques dans la baie de Somme entre 1981 et 1987. Une surpopulation de l'annélide *Pygospio elegans* s'est produite lors de la crise de production de la coque (*Cerastoderma edule*) en 1984-1986, suivie d'une régression complète et rapide en 1987, lors du retour du bivalve.

ponse of key-species is quick and strong (i.e. *Pygospio elegans*, *Cerastoderma edule*, *Heteromastus filiformis*) (figure 5) and absent or weak for target-species whose fluctuations are governed by broader scale environmental factors like climate (i.e. answer of *Macoma balthica* after the severe winter of 1985).

In addition to the monitoring of the abundance of key and target species, other topics deal with the detection of « signals » corresponding with stress endured by the animals : growth deficiency, reproductive cycle, decreasing productivity, lower P/B ratio.

The « cockle survey » in the Bay of Somme illustrates the application (figure 6) of this type of research work (DUCROTOY *et al.*, 1987). Twice a year (April & September), the *Cerastoderma edule* populations are sampled. Digital processing and computer-assisted map analysis were developed to check the validity of the selected sampling step. Each of the 140 stations is then localised in space and time within a homogenised and structured ensemble thanks to a three dimensional diagram (RYBARCZYK *et al.*, 1988). Demographic studies (LEMOINE *et al.*, 1988) were carried out in order to :

— assess the stocks (biomass & numbers) for fishery management,

— explain populations turns-over (recruitment, mortality),
— link state variables (density, age-groups, growth) with physical (temperature, sedimentology, altimetry), chemical (pollutants, fertilizers...) and biological (associated in-fauna) factors

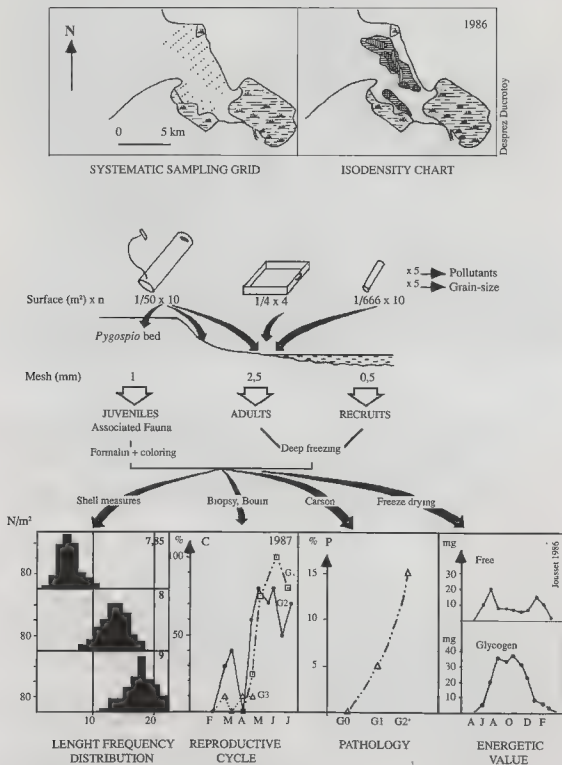
From observation of pilot-stations, selected to represent the typical estuarine community, information is gathered on :

— growth patterns and mortality of bivalves throughout seasons, energy budget and reproductive cycle of the cockle,
— benthos population dynamics
— polluted water dynamics throughout the estuary and water quality assessment : this new line of research was started in 1988 to mesure the impact of eutrophication which was proved to be responsible for local economic problems (cockles, flat fishes, shrimps...).

CONCLUSION : FUTURE PROSPECTS

The multiplication of research programmes these last ten years at the Station d'Etudes en Baie de Somme shows the importance of the Bay of Somme ecosystem as related

COCKLE SURVEY



to its position along the English Channel as well as to fishing and aquaculture resources. Focusing on the cockles proved to be fruitful and several interesting points emerge from these studies :

- interchangeability of species in these particular communities,
- trophic capacity assessment,
- the influence of local and climatic disturbances on population dynamics:
 - * eutrophication,
 - * rising sea-level,
 - * climatic changes,
- future of the estuary and instructions for managing such an ecosystem, especially by rejuvenating old polders.

The problem of the cockle population turn-over leads to a new approach for the whole estuarine ecosystem : is the Somme macrotidal estuary to be considered as an open or closed system ? The geographical approach would outline the large mouth of the river towards the open-sea system but, from the biologist's point of view, exchanges must be limited between the two systems.

Recent works on the « coastal flow » along the southern part of the Channel point out that a real physical limit exists ten miles from the coast line. A reduced « permeability » between waters circulating in the estuary and the sublittoral waters must then be considered. From the knowledge of the variation in hydrodynamical phenomena throughout the seasons, rapid changes in the coastal flow limiting the estuary must also be thought of. This phenomenon would lead to changes in the evolution of certain parameters which cannot be foreseen presently. A new concept of transfers between littoral and estuaries should then be proposed.

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FIG. 6 — The cockle survey in the Bay of Somme (France). *Technique d'inventaire de la Coque dans la Baie de Somme.*

* LENGTH FREQUENCY DISTRIBUTION

* DISTRIBUTION DES FRÉQUENCES DES CLASSES DE LONGUEUR

Length of antero-posterior axis of shell in mm
 Nmm² : numbers per square meter in July, August and September 1985
 Longueur de l'axe antéro-postérieur de la coquille (mm)
 Nmm² : effectifs par mètre carré en juillet, août et septembre 1985

* REPRODUCTIVE CYCLE

* CYCLE DE REPRODUCTION

Time in months
 Rate of individuals reaching C maturity-stage :
 matured gonad and imminent spawning
 G1 : animals born in 1986
 G2 : animals born in 1985
 G3 : animals born in 1984
 Temps en mois
 Taux d'individus atteignant le stade de maturation C :
 gonades mûres et fraie imminente
 G1 : animaux nés en 1986
 G2 : animaux nés en 1985
 G3 : animaux nés en 1984

* PATHOLOGY

* PATHOLOGIE

Rate of animals contaminated by *Labratrema* sp. from February to July 1987.
 G0 : animals born in 1987
 G1 : animals born in 1986
 G2+ : animals born before 1986

Pourcentage d'animaux contaminés par *Labratrema* sp. de février à juillet 1987

G0 : animaux nés en 1987
 G1 : animaux nés en 1986
 G2+ : animaux nés avant 1986

* ENERGETIC VALUE

* VALEUR ÉNERGÉTIQUE

Time in months in 1985
 Concentrations in mg/g of dried meat
 (after JOUSSET, 1986)
 Temps en mois en 1985
 Concentrations en mg/g de matière sèche (d'après JOUSSET, 1986).

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THE INSHORE BRACKISH WATER DOMAIN OF THE FRENCH ATLANTIC COAST : ECOLOGICAL FUNCTIONS FOR THE EXPLOITED SPECIES-IMPACT OF PHYSICAL DEVELOPMENT*

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MOTS CLÉS : France, côte atlantique, eaux littorales, espèces commerciales, impacts physiques de l'homme.

KEY WORDS : France, Atlantic coast, coastal waters, commercial species, physical man-induced effects.

RÉSUMÉ

LE DOMAINE PRATIQUE DE LA CÔTE ATLANTIQUE FRANÇAISE : FONCTIONS ÉCOLOGIQUES POUR LES ESPÈCES EXPLOITÉES-IMPACT DES AMÉNAGEMENTS. Composé de milieux diversifiés, le domaine pratique abrite de manière permanente ou temporaire, une faune d'intérêt halieutique majeur (poissons, crustacés), constitué essentiellement d'espèces soit autochtones, soit amphihalines, soit euryhalines d'origine marine.

Ces milieux remplissent pour ces espèces un certain nombre de fonctions vitales pour le bon déroulement de leurs cycles biologiques (zone de reproduction et/ou de nurseries, et/ou de croissance, et/ou de passage).

Certaines activités humaines, par les aménagements physiques qu'elles entraînent (creusement, endiguement, comblement de vasières, barrages, pompes...) font peser des menaces sur l'intégrité de ces systèmes et les fonctions qu'ils remplissent. Selon l'espèce considérée et son degré de dépendance vis-à-vis du domaine pratique, la conséquence d'un aménagement à ce niveau sera plus ou moins essentielle. Des exemples d'impact de certains de ces aménagements, étudiés récemment, sont décrits et analysés.

SUMMARY

Composed of diversified environments, the brackish water areas support either permanently or temporarily sealife of major importance to fishing (fish, crustaceans), mainly composed of autochthonous, amphihaline or euryhaline species of marine origin. These environments fulfill a certain number of vital functions for their species' biological cycles (spawning and/or nursery zones, and/or growth, and/or movement).

Certain human activities, by the works they entail (digging, embanking, filling, damming, pumping...) threaten the entirety of these systems and their functions. According to the species considered and its dependence vis-à-vis the brackish water domain, the consequences of development at this level will have more or less impact. Recently studied examples of the impact of some of these measures are described and analysed.

THE CONCERNED ENVIRONMENTS

The coastal brackishwater domain includes all the environments, except marine and continental, that have a connection with the sea (GUELORGUET *et al.*, 1983). From the River Vilaine to the « Bassin d'Arcachon » this connection concerns considerable surfaces, that are regularly submerged and emerged because of the important tidal range. In addition, nearly all these environments are significantly influenced by continental freshwater drained from more or less wide catchment areas (200 to 120.000 km²).

It would be irrelevant, in this paper, to classify these hydrosystems according to the very numerous morphological, hydrological or hydrobiological criteria (CLARK, 1974 ; GUELORGUET *et al.*, 1983 ; KIENER, 1978 ; LASSERRE, 1979 ; VERGER, 1968). We only emphasize that, between the River Vilaine estuary and the « Bassin d'Arcachon », at least 220.000 to 250.000 ha are concerned (FIG. 1), including :
— estuaries : 50 % of this surface ;
— coastal brackishwater in dammed up marshes : 15 % ;
— others (baie de Bourgneuf, bassin d'Arcachon) : 35 %.

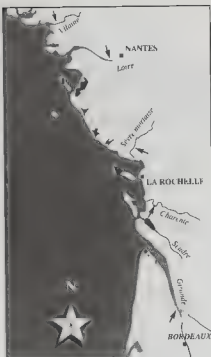
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FIG. 1 — Brackishwater environments of the French Atlantic coast from the Vilaine estuary to the « Bassin d'Arcachon ».

Milieux saumâtres de la côte atlantique française entre l'estuaire de la Vilaine et le Bassin d'Arcachon

- ← Max limit of salinity (0,5 ‰)
- Brackish littoral dammed up marshes
- ← Limite maximum de salinité (0,5 ‰)
- Marais littoraux saumâtres endigués



ICHTHYOLOGICAL AND CARCINOLOGICAL COMMUNITY AND BIOLOGICAL IMPORTANCE OF THESE ENVIRONMENTS FOR THESE SPECIES

BIOCENOTICAL ORIGIN OF THE SPECIES

Between ocean and continent, the brackishwater systems receive a very rich animal community composed with more than a 100 species (fishes and crustaceans) that are more or less dependant on these systems according to their biological needs and to their native hydrosystem (ocean, coastal brackish environments, continental fresh waters). Thus, we distinguish :

— the **amphihaline species** : they are either sea spawners (*A. anguilla*, *Platichthys flesus*), or freshwater spawners (*S. salar*, *S. t. trutta*, *Osmerus eperlanus*, *Alosa sp.*, *Petromyzon marinus*) ;

— the **euryhaline sea spawners** : between april and the end of september, during some of the ecophasis of their biological cycle, they live in the coastal brackishwater systems (mainly 0 + and 1 + age groups of *Solea solea*, *Dicentrarchus sp.*, *Liza aurata*, *Liza ramada*, *Chelon labrosus*, *Clupea harengus*, *Sprattus sprattus*, *Palaemon serratus*, *Crangon crangon*) ;

— the **autochthonous brackishwater spawners** : they are able to carry out their entire biological cycle in coastal brackishwater systems (*Palaemon longirostris*, *Palaemonetes varians* (white shrimps), *Carcinus moenas*, *Atherina sp.*,

Pomatoschistus sp., *Gasterosteus aculeatus*...) ;

— the **euryhaline freshwater spawners** : sometimes dragged away to the brackishwater systems, their presence is accidental (*Ictalurus melas*, *Abramis brama*, *Suzostedion luciopectra*, *A. alburnus*...).

BIOLOGICAL IMPORTANCE OF THESE SYSTEMS FOR THESE SPECIES.

According to their biocenotical origin, these environments play at least one of the following roles :

— **trophic role** : because of their high biological production (MANAUD & MONBET, 1980), the coastal brackishwater systems receive important spring and summer concentrations of euryhaline marine spawners and of amphihaline species (ex : Flounder), thus they serve as nurseries (DESAUNAY *et al.*, 1980 ; GASCUEL, 1985 ; LARDEUX, 1986 ; MARCHAND & ELIE, 1983 ; MASSON, 1987). These environments also allow the sedentarisation of amphihaline sea spawners (*A. anguilla*) ; and therefore, constitute privileged sites of their distribution area ;

— **physiological role and compulsory migrating way** : for the amphihaline species, most of these environments constitute the only passage between the sea and continental waters and permit progressive accommodation to the change of salinity (FONTAINE, 1976) ;

— **genetic role** : for the autochthonous species, some indispensable spawning areas take place in these hydrosystems (LABOURG, 1976).

According to the level of dependence of these species on the coastal brackishwater systems, interference with the integrity of these environments will have more or less important impact.

SOCIAL AND ECONOMIC IMPORTANCE OF THE EXPLOITATION OF THESE SPECIES

Most of the species mentioned have high commercial value. The maintenance and even the development of fishing these species, in both brackish environments, either in the coastal areas or continental fresh waters. This exploitation is interesting for several reasons :

— **at a cultural level** : they allow the maintenance of traditional fisheries and of much appreciated special dishes in many regions ;

— **at an economic level** : if the production of coastal and estuarine fisheries was better known not long ago, those of the dammed up marshes and of the freshwater areas still have to be precised. Only few recent data [ANONYME, 1984 ; ELIE & MARCHAND, 1983 ; FEUNTEUN *et al.*, (sous presse)] allow us to predict a high level of production in these zones ;

TABLE 1 — Production and known value of the main exploited species which the perennality of which depends on the integrity of the coastal brackishwater systems of the Atlantic littoral (CASTELNAUD, 1988 ; ELIE and al., 1988, LEAUTE, comm. pers.).

Production et valeur connue des principales espèces exploitées dont la pérennité dépend de l'intégrité des eaux saumâtres du littoral atlantique

SPECIES	TONNAGE	VALUE
		Millions of F
EURYHALINE SEA WATER SPAWNERS (1985)		
• Sole (<i>Solea Solea</i>)	2664	125,3
• Plie (<i>Pleuronectes platessa</i>)	283	1,2
• Bar (<i>Dicentrarchus labrax</i>)	1552	85,2
• Hareng (<i>Clupea harengus</i>)	17	0,05
• Mulet (<i>Mugil sp</i>)	482	2,9
• Crevette grise (<i>Crangon crangon</i>)	230	8,5
AUTOCHTHONOUS BRACKISHWATER SPAWNERS (1985)		
• Crevette blanche (<i>Palaemon longirostris</i>)	80	4,0
AMPHIHALINE (1985)		
• Anguille - civelle (<i>Anguilla anguilla</i>)	215	49,9
sub-adulte (<i>Anguilla anguilla</i>)	478	16,9
• Alosa (<i>Alosa alosa</i> et <i>Alosa fallax</i>)	526	12,5
• Lampreues (<i>Petromyzon marinus</i> et <i>Lampetra fluviatilis</i>)	114	10,2
• Salmodontes (<i>Salmo salar</i> et <i>Salmo trutta trutta</i>)	21	6,7
TOTAL	6 662	323,35

— at a social level : in the considered regions, the catching of the only amphihalines concerns about 1,100 sea fishermen, 400 professional river fishermen and hundreds of thousands of amateur fishermen (traps, rods).

TYPES OF DEVELOPMENTS IN THESE ENVIRONMENTS

Because of their strategic situation (close and open to the sea, outlet of catchmen areas, easy access), these environments have been, and continue to be more and more exposed to various types of physical development that, most often, do not aim to take advantage of the biological richness of these areas. Thus, one can distinguish for instance : building of dams and water-gates : dredging and clearing mud for regular maintenance of navigation channels ; embanking and damming up extremely wide tidal areas (lateral siltbanks, tidal flats) ; edification of thermal and nuclear power stations with water pumping and elimination of cooling waters into the estuaries.

We will now describe precisely a few recent investigations which illustrate these various cases

EXAMPLES OF PHYSICAL DEVELOPMENT IMPACTS

DREDGING AND EMBANKING

In the River Loire, the maintenance and development of industrial and harbour activities required and still require many development works. These include, among other creation and maintenance of navigation channels. Because of these works, the average depth of the estuary has increased from 1 to 6 meters. Regular maintenance of the navigation channels requires a yearly dredging of 6 millions of m³ of sand and mud, there only creation required the shrinkage to 55 millions of m³.

The impact of these developments is a much debated question (OTTMANN, 1985), and is very difficult to quantify. While some effects are measurable (modification of the currents, recession of the salinity front, putting back in suspension of fine sediments), dredging involves the destruction of the benthic fauna, and renewed suspension of fine sediments and of chemical or bacteriological pollutants which are usually « trapped » in the silt. All of these are phenomena whose impact on fishes is very difficult to assess. Moreover the depositing of spoiled materials on islands (banks of Pipy and of Bilho in River Loire) (MOUGANI, 1982), or on lateral silty tidal flats, has sterilised hundreds of hectares of highly productive areas (more than 8 tons of fresh matter per ha and per year) (MARCHAND *et al.*, 1983) ; and also put an end to the estuary/annex marsh exchanges, disturbing the fundaments of the estuary's biological functioning (MARCHAND, 1977 ; MARCHAND & ELIE, 1983 a and b).

DAMMING UP

Since the XII century, huge areas (245,000 ha) have been dammed up on the silty strands for salt production and for agriculture. The importance of the relations with the sea was progressively controlled by numerous, individual or collective water gates. According to the interest given to these environments (hunting, fishing, aquaculture, agriculture, salt production...), various development and management policies were applied (BAUDET *et al.*, 1987 ; CLÉMENT, 1986 ; LABOURG *et al.*, 1980). Their consequences are either the maintenance of water (fresh or brackish), or natural or deliberate filling in. Nowadays, 85% of these dammed up marshes are maintained with fresh water and have thus lost their brackish character and associated roles. A second development phase is under way in some former salt production areas (ex : marsh of Moeze-Brouage near Rochefort) where draining and flattening take place in marshes to permit agricultural intensification (LEROUX, 1983). As to management with of brackish water, because of the existence and of the management of watermarshes

gates, because of the creation of pools in the marshes (20 % to 50 % of the whole surface), because of the development of several activities that often have nothing to do with the natural resources of the environment, the embanking has ruined highly productive areas (tidal flats), and is responsible for the deterioration of the specific richness of communities, and also of their abundance.

The recent embanking of 80 % of the Loire estuary, and regular dredging of the navigation channel end with the destruction of crucially productive areas. The disappearance of nearly all the *Palaemon longirostris* (white shrimp) populations (*autochthonus species*) in this estuary seems to be related to these developments (MARCHAND *et al.*, 1983).

DAMS AND SLUICE GATES

The Arzal's estuarine dam, built 17 years ago, strongly disrupted the fluvio-estuarine system of the River Vilaine (ELIE & RIGAUD, 1984). It was recently shown that the occlusion of this hydrosystem is responsible for the total vanishing of this river's drainage basin, of several species such as : *Acipenser sturio*, *Alosa alosa*, *Alosa fallax*, *Salmo salar*, *Salmo trutta trutta*, and has greatly disturbed the colonization of this environment by the Eel (*Anguilla anguilla*). Arzal's dam constitutes a physical obstacle for the elvers of this species and makes their capture easier at this biological stage because of the concentration of the fishing fleet downstream, next to the dam.

Besides, this has totally changed the hydrobiological conditions involving disturbances : upstream (more or less total drying of very productive wetlands) ; downstream (increasing of silt deposition, modifying currents and haline stratification). After high fish mortality (several dozens of tons) was noted in the bay of Vilaine (due to an important oxygen shortage in July 1982), an analysis of this phenomenon's causes and mechanisms was carried out. The synthesis of the first results (MERCERON, 1988), confirms that Arzal's dam is a largely responsible for the fragilisation of this zone, because it reduced the estuary to one fifth of its former length. Thus its estuarine functions, as consumers of oxygen (mineralisation of the organic matter and nitrification), were shifted into the bay of Vilaine.

The numerous small water gates that were built in coastal marshes to control exchanges between them and estuaries, are also responsible for this kind of problem (FEUNTEUN *et al.*, (sous-presse) ; LEGAULT, 1986 ; MARCHAND & RIGAUD, 1984). Their presence reduces, and can even stop exchanges, thus the functions of these areas are now greatly lowered, especially for amphihaline species (eel) or euryhaline sea spawners (sea-bass), and for the relevant declining fisheries.

WATER PUMPING

The study of BOIGONTIER *et al.* (1984, 1985) serves as a model because it allows to assess the quantity of macro-organisms trapped by this kind of industrial activity in an estuary. In addition, after the calculation of mortality rates of the biological stages in each species (*in situ*), the destruction caused by pumping water at the nuclear power station of Blayais were quantified.

For some biological components, this study enables us to compare the relative impact of this activity on the catches that fisheries take in the Gironde estuary. Thus, the authors establish that the quantities of grey and white shrimp destroyed by water pumping, are roughly the same as those caught by the fishing fleet in this hydrosystem.

CONCLUSION

Still relatively unknown, closely bound to coastal waters and to adjacent river catchement areas, the brackish water systems of the atlantic coast play crucial roles for many amphihaline species and for many euryhaline sea water spawners of major commercial interest. The numerous aggressions (development works but also degradation of water's quality) to which these areas are subject, have direct consequences on the fish and crustacean stocks and

TABLE II — Estimation of quantities of organisms (number and weight) killed throughout a year at the thermonuclear power station of Blayais : June 1984 - mai 1985 (BOIGONTIER *et al.*, 1985)

Estimation des quantités d'organismes (nombres et masses) récupérés en un an (juin 1984 - mai 1985) à la centrale nucléaire du Blayais (BOIGONTIER *et al.*, 1985)

SPECIES	KILLED QUANTITIES	
	NUMBER x 1000	WEIGHT by kg
* Crevette blanche (<i>Palaemon longirostris</i>)	105624	41712
* Crevette grise (<i>Crangon crangon</i>)	66681	12283
* Eperlan (<i>Osmerus eperlanus</i>)	0+ ≥ 1+	26271 29142 1283 9569
* Alosa (<i>Alosa alosa</i>)	0+	741 1328
* Gade (<i>Alosa fallax</i>)	0+ ≥ 1+	2363 3408 245 3075
* Mulet (<i>Mugil sp.</i>)	0+ ≥ 1+	34 157 3 206
* Sprat (<i>Sprattus sprattus</i>)		1569 15352
* Gobie (<i>Pomatoschistus minutus</i>)	0+ ≥ 1+	173243 29957 2181 753
* Syngnathie (<i>Syngnathus rostellatus</i>)	0+ ≥ 1+	11066 960 49953 66430
* Anchois (<i>Engraulis encrasicolus</i>)		147 93
TOTAL		441404 214435

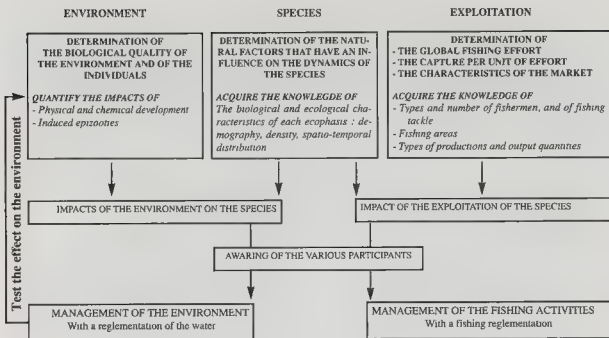


FIG. 2. — Theoretical pattern of management of coastal brackish waters *Plan de gestion théorique des milieux saumâtres littoraux*

fisheries. If some of these consequences have been shown, the great majority of them still have to be investigated and established. Nevertheless, only the knowledge and the relativisation of these impacts, especially towards the dynamic of species, will permit us to propose reasoned management and development policies for these potentially high productive systems. These studies are too recent and most often too incomplete (because carried out on too short periods), to yet allow to shore up this approach. In the future, a sustained research program will have to be carried out according to the following kind of pattern [FIG. 2 in ELIE (1985)]; that is the only way to be able to manage the « coastal brackish water space », and its associated species.

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AN EXAMPLE OF DEVELOPMENT FOR AQUACULTURE IN FRANCE : THE SHELLFISH-CULTURE POLDERS IN THE BAY OF BOURGNEUF*

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MOTS CLÉS : polders, conchyliculture, mariculture, eaux souterraines, protection de l'environnement.

KEY WORDS : polders, shellfish culture, mariculture, subterranean waters, environment preservation.

RÉSUMÉ

SUMMARY

UN EXEMPLE DE DÉVELOPPEMENT DE L'AQUACULTURE EN FRANCE : LES POLDERS DE LA BAIE DE BOURGNEUF.

Sur la côte Ouest-atlantique française, la baie de Bourgneuf constitue une zone conchylicole importante située au sud de l'estuaire de la Loire. Depuis la seconde guerre mondiale, cette zone a subi des aménagements, notamment dans les marais qui bordent la baie. En particulier, la construction de polders a permis l'installation de nouvelles activités : l'affinage des huîtres en claires d'abord, puis plus récemment la culture de la palourde et de la crevette japonaises, aidés par la possibilité de stockage de l'eau de mer dans les polders et par la découverte récente d'eaux souterraines salées à température constante de 14°C environ. Ainsi, par leurs caractéristiques hydrauliques, par la qualité de leur eau pour la culture du phytoplancton, les polders de la baie de Bourgneuf constituent des systèmes permettant une optimisation et une diversification des produits aquacoles. Toutefois, les nouveaux aspects culturels exigent de maintenir une extrême prudence vis-à-vis des écosystèmes côtiers et de leur environnement.

On the west-atlantic coast of France, the Bourgneuf Bay represents an important shellfish breeding zone located at the south of the Loire estuary. Recently, this zone has been developed, particularly in the marshes which lie along the bay. Thus, the organization of new polders has permitted the development of new activities : first the maturing of oysters in land ponds called « claires » ; then Japanese clam and prawn breeding by stocking the sea-water in the polders and also by pumping and using subterranean salt waters which are nutrient rich and at a constant temperature of 14°C. Thus, the hydraulic system of the polders and quality of the subterranean-waters for phytoplankton production constitute excellent tools for diversified aquaculture. Nevertheless these modern techniques require careful attention for the environment as preservation.

INTRODUCTION

On the French Atlantic coast, the Bourgneuf Bay represents an important shellfish breeding zone situated on the Marais-Breton-Vendéen, a vast low-lying area covering over 36.000 ha south of the Loire. Active traditional aquaculture oriented mainly towards oyster culture is located on the littoral : 10 to 12.000 tons of oysters a year are currently produced on a wide foreshore, covering about 10.000 ha, at low tide springtides. At the far eastern end of the bay, the 15 km long artificial coast is bordered by a system of dikes which shelter polders supporting various activities : intensive mixed farming and also several shellfish-culture sites recently set up to stock and mature

oysters during the final breeding period, as well as new cultures such as clam breeding.

The shellfish polders constitute unique hydraulic units giving hope for application of new techniques in aquaculture for molluscs, shellfish or even fish. Such techniques are being studied at the two IFREMER experimental stations set up in two areas of the Bourgneuf Bay where new polders have been created. Several of these have already been transferred to oyster-breeders. Thus, the recently organised polders are the object of our attention because of the unusual way of managing seawater, the innovative aspect of the aquaculture techniques used and finally be-

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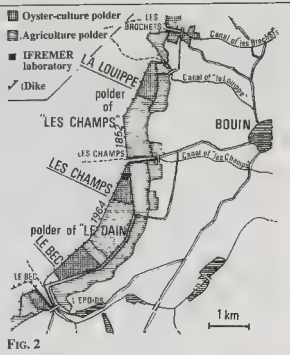
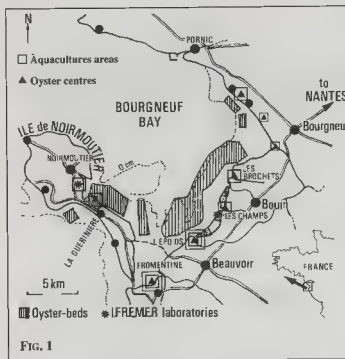


FIG. 1 — Geographic location of the Bourgneuf Bay. Localisation géographique de la Bate de Bourgneuf.

FIG. 2 — The « polders des Champs » and the « polder du Dain »: the existing shellfish culture zones, La Louippe, Les Champs and Le Bec. Les polders des champs et le polder du Dain : les zones d'élevage de mollusques et de crevettes, la Louippe, Les Champs et le Bec.

cause of the possibility of further expansion of areas dedicated to aquaculture in the Bourgneuf Bay. However attractive they may be, these new areas of development are not without consequences for the environment and the ecological balance in the surroundings; even in the polders themselves and their neighbouring zones.

GEOGRAPHIC SITUATION AND ORGANISATION OF THE SHELLFISH-POLDERS IN THE BOURGNEUF BAY

GEOGRAPHIC SITUATION

Centuries of successful land reclamation, particularly since the XVIII^e century, have given a straight edge to the modern shoreline of the far end of the bay as well as the eastern coast of the Ile de Noirmoutier, of the south-west limit of the bay (Fig. 1). We will not give any details here on the history of the development of the polders, already described by GAUTIER (1972) and MOUNES (1974). Besides, all these polders were intended for agricultural production, the most recent of them being used for intensive cereal and fodder cultures. We will only mention the recent works under development for aquaculture :

the « polder des Champs » and the « polder du Dain » (Fig. 2) within whose boundaries three shellfish-culture zones (La Louippe, les Champs and Le Bec) extend over about 100 ha.

The « polder du Dain » covers about 200 ha. The district of Bouin owns the polder and opted as early as the 60's for a development intended for marine cultures, which represented a daring wager at that time. 160 shellfish-culture centres have been created : 20 ha are being developed (CORLAY & ROBERT, 1986). This is the area where new cultures have most widely expanded, helped by the presence of the IFREMER experimental laboratory. The « polder de la Louippe », northern part of the « polder des Champs » (Fig. 2) covers 30 ha or so. It was set up earlier and its main characteristic lies in the oyster maturing units for the final stage of the breeding of molluscs.

ORGANISATION OF AN OYSTER-CULTURE POLDER : EXAMPLE OF THE « ZONE DE LA LOUIPPE »

The « zone de la Louippe »'s main assignment is the maturing of oysters, that is to say their fattening and occasionally their « greening ». This phenomenon, localised in the gills and the labial sensors of molluscs is due to the proliferation of a Diatom, *Haslea ostrearia* whose distinctive feature is to synthesize and then release into the envi-

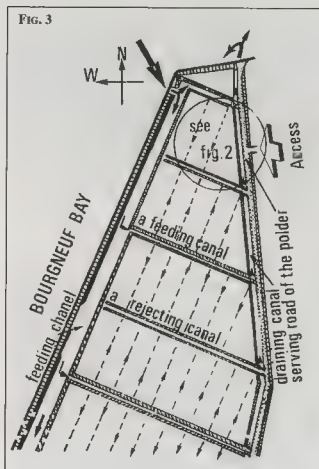


FIG. 3 — Organisation of the « zone de la Louppe » for maturing of oysters in the « polder des Champs ».
Organisation de la zone de la Louppe pour l'affinage des huîtres dans le polder des Champs.

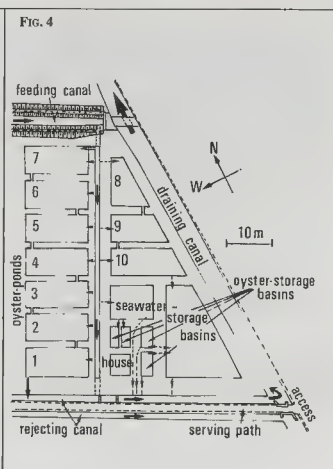


FIG. 4 — An oyster-culture farm in the « zone de la Louppe » : organisation of oyster-ponds.
Une installation de culture d'huîtres dans la zone de la Louppe : organisation des clairens

ronment a greenish-blue pigment, the « marennine » (ROBERT, 1986). The maturing of oysters is achieved in land ponds covering an area of 400 m² and 60 cm deep called « clairens ».

In this polder, the system of supplying the « clairens » with seawater consists of a feeding channel in direct contact with the sea when the tide coefficient is higher than 60, and several feeding canals distributing seawater to the different farms (FIG. 3). The rejected waters are drained off by canals situated on either side of the paths serving the units and running into a main draining canal opening into the sea by a valved floodgate. The farms are spread out in plots alongside the serving paths and are composed of about 10 « clairens » (FIG. 4). This pattern of organisation is generally the same in the other polders recently developed. It could be extended to all the polders of « Les Champs » and « Le Dain », over a potential area of 180 ha or so, as well as other zones turned into polders on the Ile de Noirmoutier.

THE PRESENT AND FUTURE ASSETS OF POLDERS FOR AQUACULTURE

THE PRESENT ASSETS

The polders developed in this manner consist of independent hydraulic units, subject to the sole influence of the coastal waters which are introduced into them. For instance, the salinity of the waters feeding the « clairens » of « La Louppe » varies between 24 and 36,5 ‰ according to the season with extreme values also being measured outside off the polders. The waters introduced into the polders are rich in mineral nutrients (nitrogen, phosphorus, silicon) whose supply in the « clairens » leads to a primary production directly transferable to the molluscs being bred. We estimate an average fixation of a ton of carbon per ha of « clairens » and per year in the « polder de La

Louippe » (ROBERT, 1983), only in the aquatic compartment, without considering the benthic production. This estimate is close to the one of a non eutrophied coastal area. These examples enable us to hope for an improvement in the production of the different links of the trophic chain : either by increasing the rate of renewal of waters in the ponds : or by providing nutrients at a higher concentration owing to various fertilization processes.

Among these processes, there is one which applies especially to polders themselves. Indeed, the subsoil of these zones (Eocene limestone and sands) contains, at a low depth, a reserve of salt waters (the salinity ranges from 16 to 38 ‰), extremely rich in nutrients, sometimes to an excess for some of them, particularly as regards ammonium and iron. Moreover, the temperature of these waters always ranges from 12 to 15° C. They are already used in the rough or after being mixed with seawater for mass production of natural phytoplankton or unicellular algae under breeding, chiefly the *Skeletonema costatum* Diatom.

The availability of seawater, its high nutrient content, its control by canals, the possibility of improving the initial production thanks to fertilization, the presence of subterranean waters with constant temperature whatever the season, the new and rational organisation of ponds in farms are many of the deciding factors for introducing new types of maricultural activities in the polders

NEW TYPES OF AQUACULTURE ACTIVITIES IN POLDERS AND DIKED SALT MARSHES

Not essentially based on shellfish breeding, they apply to bivalve molluscs but also to prawns and fish.

The Japanese clam *Ruditapes philippinarum* is now one of the new species bred in the polders of the Bourgneuf Bay. The 2 to 3 mm seedclam is prefattened in private nurseries : at the present time, the number of these in the « polder des Champs » and the « polder du Dain » amounts to 8. The nurseries use the nutritional and thermic resources of the subterranean salt waters, that is to say their constant temperature (about 14° C) and their high nutrient contents : particularly during the winter stage from November to February during which the molluscs would not normally be able to feed themselves because of temperatures under 8 to 10°C. This enables professionals to reduce breeding time by six months in comparison with the usual practice which does not take into account subterranean waters. The prefattened clams are then sown on the ground either in clam ponds (50 to 100 individuals.m²) or on the foreshore (150 to 200 individuals.m²).

Hopefully aquacultural productions will eventually include the « king prawn », *Penaeus japonicus* : for either intensive breeding, 1 to 3 individuals.m²; or semi-intensive breeding, 6 to 10 individuals.m² with added compound food. The AQUALIVE station of IFREMER car-

ries on research on this activity : some tests with professionals have started and a manne farm grouping clam and prawn breeding is being set up in the Ile de Noirmoutier.

As far as fish are concerned, sea-bass and sea-ream (*Dicentrarchus labrax* and *Sparus aurata*) are the marine species which give most hope for the future. The density of individuals under breeding depends on the renewal of water and oxygen in ponds. Resistance to low winter temperatures can be improved by circulating subterranean salt water in plastic tunnels immersed in the ponds. All these methods are tested at the IFREMER laboratory of Noirmoutier.

DISCUSSION AND CONCLUSION

The polders for shellfish breeding in the Bourgneuf Bay constitute excellent existing and potential tools for a diversified aquaculture. However, the development of new culture practices is limited by the technologies used, and the impact of breeding activities on the environment and between themselves and also to land structures.

The building of dikes has partly eliminated the vegetable structures of slikke and schorre at the far end of the bay. It is also known that dikes break natural exchanges between the sea and the marshlands : the passing of fish ; the flow of nutrients towards the sea, is reduced for some, increased for others (ROBERT, 1984).

The future choice of using unexploited lands turned into polders has not yet been clearly established : there is a runaway in the middle of the « polder du Dain » next to a remarkable ornithological reserve. Which priorities should be given for future developments ? If aquaculture is to be extended, the priority is the quality of the waters of the coastal and marine surroundings. Can we uphold the quality of canalised water flowing out of the farm land ?

The quality of the marine environment must not be disturbed by the breeding themselves. It has already been noticed that the proliferation of green macrophyte seaweeds may be linked with nitrogenous and phosphorous dissolved matter rejected by breeding organisms or by subterranean rejected waters whose nutrient reserve has not been totally used up in cultures. The proximity or even the mixed-breeding of organisms as different as molluscs, shellfish or fish can also create problems of parasitic pathology. Such observations show which future problems might be created by the choice of such individualised systems directly linked with the sea. Thus, the regional administration together with scientists are searching for solutions for the rational organisation of this environment. Much more scientific work should be carried out : indeed, the faster the evolution of aquacultural techniques, the greater the environmental problems.

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FUNCTIONING OF THE PLANT COMPONENT IN DENSELY STOCKED FISHPONDS*

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MOTS CLÉS : Tchécoslovaquie, dioxyde de carbone, gestion des étangs de pisciculture, oxygène, plantes aquatiques.

KEY WORDS : Czechoslovakia, carbon dioxide, fishpond management, oxygen, water plants.

RÉSUMÉ

LE FONCTIONNEMENT DE LA VÉGÉTATION DANS LES ÉTANGS DE PISCICULTURE INTENSIVE.

Les étangs de la Bohême du Sud, créés du 14^{ème} au 15^{ème} siècles, sont restés oligo-ou mésotrophes jusqu'au 20^{ème} siècle, puis une exploitation intensive a provoqué une eutrophisation accélérée. L'apport d'éléments nutritifs et la sédimentation accrue provoquent une augmentation de la productivité des macrophytes et des algues microscopiques, dont la dominance est favorisée par la prédation d'une population dense de carpes, les hydrophytes vasculaires ne pouvant prédominer que dans les étangs avec une faible densité de poissons. La concurrence pour la lumière et les éléments nutritifs entre hydrophytes et phytoplancton a pour conséquence la concentration de la biomasse végétale près de la surface et la forte dominance d'un petit nombre d'espèces particulièrement compétitives. Ces conditions favorisent aussi la prolifération du périphyton. La rapide consommation du carbone inorganique par la photosynthèse, en induisant des valeurs élevées du pH, crée de mauvaises conditions pour la productivité des poissons. L'apport de calcaire favorise les plantes capables d'utiliser le bicarbonate, le pH atteignant alors une valeur de 9 environ et l'ammoniaque dissoute une concentration nocive pour les poissons.

This paper deals mainly with the impact of the present-day management on South Bohemian fishponds which were built in the 14th to 15th centuries (SUSTA 1898, KRUPAUER 1971, MATENA & BERKA 1987). As the local soils are poor in nutrients, the original character of these ponds was oligo- to mesotrophic. Fish (90 % common carp, *Cyprinus carpio*) production has increased and the fishpond vegetation has markedly changed during the last two decades through intensified management of nearly all the ponds (HEJNÝ *et al.* 1982).

SUMMARY

The ponds of southern Bohemia, created in the 14th - 15th centuries, remained oligo- or mesotrophic up to the 20th century, when intensified fish production caused increasing eutrophication. Nutrient input and growing sedimentation allow for an increase in macrophyte and microscopic algae productivity. The dominance of the latter is favoured by carp grazing when the fish density is high, vascular hydrophytes being dominant only with low fish density. The competition for light and nutrients between hydrophytes and phytoplankton results in the concentration of biomass near the surface and in the high dominance of a few highly competitive species. Such conditions allow the proliferation of periphyton. The rapid consumption of inorganic carbon by photosynthesis induces high pH values, creating unfavourable conditions for fish productivity. Limestone supply stimulates the development of bicarbonate users among plants, but if the pH value reaches 9 the high resulting concentration of ammonium may kill most fish species.

Compared with the rest of the world, the management of Czechoslovakian fishponds can be regarded as semi-intensive. But its intensity can hardly be increased without damaging other useful functions of the fishponds such as water storage, maintenance of good water quality, recreation and preservation of rich plant and animal gene pools (KRUPAUER 1971, KUBU *et al.* in press).

Even now, in all densely stocked, fertilised and/or manured fishponds, the aquatic and littoral plants live and function somewhat differently from the plants that inhabi-

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ted the ponds when they were managed extensively. The intensification of fishpond management in Czechoslovakia has been associated with a progressive eutrophication of the fishponds.

Three stages of macrophyte vegetation development in relation to the degree of eutrophication and organic pollution of shallow water bodies may be distinguished (DE NIE 1987):

I — In ponds with a low load of both mineral nutrients and organic matter, the communities of aquatic macrophytes consist of a relatively high number of species. Water transparency is 2 m or more and the plant biomass is distributed evenly from water surface to the bottom; the tips of submersed macrophyte shoots only rarely reach the water surface. Species diversity of periphyton on macrophytes and of benthos near their roots is also high (KORNIKOVA 1971, DVORAK 1978). Shading and carbon dioxide uptake by periphyton do not seriously limit the growth of submersed macrophytes as periphyton is intensely grazed by molluscs, insect larvae and fish (WETZEL 1975). The concentration of oxygen in the water is mostly high and almost constant, about 100 % of air saturation; no marked differences are observed between the day and night or surface and bottom oxygen concentrations. At this stage, the aquatic primary production is essentially limited by a shortage of mineral nutrients, especially phosphorus and nitrogen, and photosynthetic uptake of CO_2 does not have any strong effect on water pH. Nowadays, fishponds of this kind are rare, not only because of more intensive fishpond management, but also because of high nutrient input from fishponds catchment areas.

II — As the mineral nutrient input to the fishponds increases by manuring and direct fertiliser application as well as agricultural runoff, macrophytes take up the nutrients, grow better, and their stands become denser. Carbon dioxide concentrations become critically low as a result of a high photosynthetic CO_2 uptake by either macrophytes or algae, or both. Phytoplankton and young green parts of macrophytes shade deeper water and most of the macrophyte biomass is concentrated at the water surface (POKORNY *et al.* 1984). Water transparency decreases; even in ponds shallower than 1 m, irradiance at the bottom may not attain the light compensation point of photosynthesis though a very low light compensation point ($< 3 \text{ W.m}^{-2}$ of PAR) has been reported for shaded submersed macrophytes such as *Ceratophyllum demersum* (POKORNY & REJMANKOVA 1983). Photosynthesis prevails at water surface while respiration does at the bottom and steep vertical gradients of oxygen concentration and pH develop temporarily between surface and bottom water. Great differences between the afternoon and early morning pH values and oxygen concentrations are typical of well-illuminated near-surface parts of the water column. The amplitude of these differences decreases with depth.

Although the species richness of plants is usually lower than at stage I, successful species of algae and macrophytes develop en masse at stage II (KOMARKOVA & MARVAN 1987, FOTT 1987). Fishponds that are slightly understocked (up to a seasonal mean fish live mass of $350 \text{ kg} \cdot \text{ha}^{-1}$) and fertilised predominantly with phosphorus fertiliser can support dense blooms of *Aphanizomenon flos-aquae* over clear water whose transparency is maintained by dense zooplankton grazing mainly on chlorococcal planktonic algae (HRBACEK 1964, KOMARKOVA 1983).

III — At this last stage, the favoured species of macrophytes are often only little grazed by molluscs, insect larvae, fish or other consumers. However, epiphytes, including filamentous algae, coat submersed parts of macrophytes, shade and deprive them of carbon dioxide: the CO_2 compensation point is lower in periphytic algae than in submersed macrophytes which eventually disappear from the ponds; this is a situation typical of densely stocked ponds (seasonal mean fish live mass over $400 \text{ kg} \cdot \text{ha}^{-1}$ or over $4000 \cdot 0.1 \text{ kg}$ carp fingerlings K_{OM} to over 300 adult carp $\text{K}_{2/3}$ per hectare). Regeneration of submersed macrophytes (from seeds or vegetative propagules) is suppressed by a dense phytoplankton dominated by chlorococcal algae, which reduces water transparency to a few decimeters. Floating-leaved macrophytes (e.g., *Polygonum amphibium*, Lemnaceae) can locally suppress the phytoplankton. A dense fish stock stirs up the bottom mud and checks the establishment of rooted submersed macrophytes at the start of the growing season. Except for a several weeks' clear-water period in spring (when the feeding activity of the carp is still low in cool water and the filtration by dense zooplankton is effective), planktonic algae dominate the fishpond plant community. Their cell numbers (10000 to 100000 cells per ml.) and chlorophyll content (up to about $600 \mu\text{g l}^{-1}$) are high (KOMARKOVA 1983), but their instantaneous biomass is low (only a few $\text{g} \cdot \text{m}^{-2}$ of organic matter at the most). Yet, because of the high turnover rate of the biomass, the annual net production by phytoplankton can be as high or higher than that in dense submersed macrophyte stands (between 0.5 and $1 \text{ kg} \cdot \text{m}^{-2}$ of organic matter per year). For further details see LOSOS & HETESA (1971), KOMARKOVA 1983), MARVAN & KOMARKOVA (1987), KORINEK *et al.* (1987), OPUSZYNSKI (1987).

With practically no permanent vegetation that would help to stabilize the aquatic community, the pond managers themselves have to keep the fishpond ecosystem in a steady state ensuring high fish production on the one hand and a reasonable water quality on the other. Special systems of fertiliser application for fishponds have therefore been elaborated (e.g., JANECEK 1971, WURTZ-ARLET 1980).

Various management measures and their consequences for the fishponds and their plant life are evaluated as follows:

- High stocking density of fish. A dense stock of carp is a good preventive measure reducing many hazards such

as water blooms and dangerous spring covers of blue-green algae on the bottom (*Oscillatoria* spp.) which often develop in clear water. A certain proportion of the herbivorous carp (*Hypophthalmichthys molitrix*) further reduces the danger of algal blooms (OPUSZYNSKI 1971). A dense fish stock also checks the macrophytes and stirs up organic-rich bottom sediments (see above); and yet sudden oxygen deficiencies caused by plant biomass or detritus decomposition occur very rarely in densely stocked ponds.

In a simplified way, the conditions in the turbid pond water may be described as follows: at daytime, the fish (carp) stay at a safe depth where there is a low concentration of ammonium gas (NH_3) and a high concentration of oxygen; the food supply is sufficient in this thin water layer. At nighttime, oxygen is consumed and carbon dioxide released by respiration and the concentrations of oxygen and carbon dioxide are even throughout the entire water column mixed by thermal convection. Oxygen deficiencies may occur in nights following cloudy days and ammonium kills caused by NH_3 released from NH_4^+ at a high pH may occur in nights following sunny days.

• Increase of alkalinity. A high pH at daytime is the result of a rapid uptake of CO_2 by photosynthesising aquatic plants (both algae and macrophytes), and the correspondingly high respiratory CO_2 release at nighttime brings about wide diurnal pH fluctuations. Water of higher alkalinity contains more inorganic carbon and, also, more molecular CO_2 at a given pH than water of low alkalinity. Fishpond managers therefore wish to increase alkalinity and thus the buffer capacity and total inorganic carbon content in water by liming (WURTZ-ARLET 1980, BILLARD & MARIE 1980). Limestone, which is now applied more often than quick lime, has a low solubility and is dissolved as bicarbonate after reacting with molecular CO_2 . The usually observed increase in alkalinity in summer may be due to the dissolution of limestone or lime after reaction with molecular carbon dioxide released by organic matter decomposition in the warming-up bottom sediments. Increased alkalinity in summer is an indication of a sufficient amount of carbonate in bottom sediments. But it is not certain whether a long term surplus of lime does not stimulate the development of bicarbonate users among aquatic plants and, consequently, the rise of pH to values higher than 8.3. A rise in pH after application of $\text{Ca}(\text{OH})_2$ or CaO is obvious and CaO should not be used at all for increasing alkalinity in waters showing a low content of CO_2 which is required for a drop in pH. Adding CaO , or intense photosynthesis, may cause the carbonisation of CO_2 -poor water, i.e., precipitation of CaCO_3 , and decrease of both effective alkalinity and total inorganic carbon concentration (BILLARD & MARIE 1980).

• Supply of molecular carbon dioxide. A dangerously high pH may result from a shortage of molecular carbon dioxide. Water plants take up carbon from bicarbonate

when pH rises over 8.3. The ratio $\text{NH}_3/\text{NH}_4^+$ is 1 at pH = 9.2, 0.1 at pH = 8.2, and 10 at pH = 10. According to SCHAPERCLAUS (1979), concentrations of NH_3 higher than 0.04 mg.l^{-1} may kill most fish species. Photosynthetic reduction of nitrate is + accompanied by greater increase in pH than is the uptake of NH_4^+ ; furthermore, when NO_3^- is taken up and reduced by aquatic plants, ammonium may be released to the water when the plants are short of inorganic carbon and left without a carbon skeleton for amino acid formation (EISELE & ULLRICH 1975, POKORNY *et al.* 1988). Bottom sediments are sometimes stirred artificially in order to suspend respiring organic materials in the water and to increase carbon dioxide concentration. At the same time, water turbidity is increased and photosynthetic uptake of carbon dioxide limited by lack of light. Dyes are even sometimes used to reduce water transparency and aquatic photosynthesis. The hazard associated with intense manuring is the introduction of products of anaerobic decomposition into the fishpond water to such an extent that the production of botulotoxin by *Clostridium botulinum* may be enhanced. Botulism, a disease causing mass kills of waterfowl, is associated with anoxic sediments rich in nitrogen-containing organic matter. It is likely that such decomposing materials as dead blue-green or filamentous algae, or manure, provide anaerobic conditions within small particles even in well aerated water. Maggots feed on these particles and transfer botulotoxin to water birds (WOBESER 1981). Manuring improves the CO_2 budget for a short time but mineral nutrients are released after mineralisation of the organic matter and an increase in biological oxygen demand (BOD) follows.

• Herbicides Paraquat and Diquat (Gramoxon) are occasionally used for water-weed control. After herbicide application, the plants die and sink to the bottom while decaying. Water transparency is increased, the numbers of some bacteria and detritivores rise and the increase in total community respiration produces more CO_2 .

Simultaneously, mineral nutrients, namely phosphate, are released from organic particles. Such conditions enhance the growth of algae and macrophytes that are resistant to the herbicide used, *Phragmites australis*, *Glyceria maxima*, Lemnaceae and filamentous algae such as *Cladophora* and *Enteromorpha* are considered to be resistant to or to be affected only temporarily by Paraquat and Diquat (NEWBOLD 1975). On the whole, however, other means of macrophyte control and an early identification of potential water weeds are preferable to their chemical control (KJET & HEJNY 1986).

Macrophytes are considered to be redundant in water bodies whose production capacity is directed toward fish production along the shortest possible food chain, i.e., phytoplankton → zooplankton → fish, because the net production of macrophytes is utilised mainly in the detritus

food chain (STRASKRABA 1968). But in highly eutrophic waters food supply is sufficient for the fish stock, which is threatened rather by highly variable and sometimes even hazardous life conditions. Such conditions, common in densely stocked and fertilized or manured fishponds, can be tolerated only by a few fish species such as the common carp, bigger carps rather than fry or fingerlings.

In an attempt to improve the ecological conditions for the fish, and especially for the fry, it will be useful to reconsider the role of macrophytes as a component stabilizing the fishpond ecosystem. The main stabilizing properties of aquatic macrophytes in fishponds are their relatively slow biomass turnover and high net production (HEJNY *et al.* 1981), their relatively high uptake of mineral nutrients which remain fixed in their biomass or detritus for some time and may be harvested when required (DYKYJOVA 1979, CULLEY *et al.* 1981, DYKYJOVA & KVET 1978, 1982) as well as the provision of shelter for young fish. The phytophilous aquatic fauna is not a negligible component of the fish diet (KORINKOVA 1971, DVORAK 1978) and waterfowl feeds intensively on some macrophytes or their parts (e.g., fruits of *Potamogeton* spp. or whole fronds of *Lemnaceae*). The detritus accumulating in macrophyte stands binds mineral nutrients and organic matter at times of their relative abundance in the fishponds and releases them gradually, according to the oxygen pattern and diffusion in the sediment (BERTRU 1980). The detritus serves as a source of food for benthos and also for filtering zooplankton when algal production is low (e.g., in early spring swarms of zooplankton are observed in warmer littoral water containing suspended detritus, SLADECEK 1973). Detritus is also the most important substrate for microbial decomposers (ULEHOVA 1976, LESEL 1980).

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THE USE OF DOMESTIC HERBIVORES IN THE CONSERVATION OF THE BIOLOGICAL RICHNESS OF EUROPEAN WETLANDS*

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MOTS CLÉS : Europe, zones humides, gestion, pâturage, herbivores domestiques.

KEY WORDS : Europe, wetlands, management, grazing, domestic herbivores.

RÉSUMÉ

L'UTILISATION DES HERBIVORES DOMESTIQUES POUR CONSERVER LA RICHESSE BIOLOGIQUE DES ZONES HUMIDES EUROPÉENNES.

Les zones humides européennes abritent diverses communautés animales et végétales et constituent des milieux relativement instables et fragiles. L'influence de l'homme, principalement par le fauchage et le pâturage, a permis de les conserver dans leur état actuel ou telles qu'elles étaient dans un passé récent. Pour maintenir la richesse biologique de nombreuses zones humides, il faut avoir recours à une gestion permettant d'éviter l'évolution vers des milieux plus secs avec développement d'espèces ligneuses, ou vers des roselières plus homogènes, dans certains secteurs tout du moins.

Le pâturage constitue un moyen très efficace de conserver les premiers stades de la succession ainsi que les communautés animales qui y sont inféodées. La coexistence d'une gamme de stades de la succession entraînant une augmentation de la diversité du milieu, il convient de bien gérer le pâturage. Les ongulés sauvages peuvent très bien être remplacés par des races domestiques. Parmi ces dernières, les taureaux et surtout les chevaux s'avèrent les plus efficaces dans les écosystèmes aquatiques. Le fait d'interdire la présence de ces animaux dans des zones protégées importantes a, par le passé, engendré des problèmes sur les plans biologique et humain. L'UICN devrait revoir ses critères pour les catégories supérieures de zones protégées.

SUMMARY

European wetlands contain diverse flora and fauna and are relatively unstable and fragile. They have typically remained in the state they are today or were in the recent past, through the influence of man, primarily through cutting and grazing. To conserve the biological richness of many wetlands management is required to prevent succession towards drier, more woody habitats or homogeneous reedbeds.

Grazing is a useful tool for the maintenance of early plant successional stages and their associated animal communities. Biological richness is increased by the coexistence of a range of successional stages; grazing therefore needs careful management. Domestic breeds are a pragmatic alternative to wild ungulates. Of these, cattle and particularly horses are the most effective for wetland ecosystems. Banning these animals from important protected areas has caused problems, biological and human, in the past. IUCN should reconsider their criteria for the top categories of protected areas.

INTRODUCTION

THE BIOLOGICAL IMPORTANCE OF WETLANDS

Wetlands are numerous and widespread across Europe. Their ecology is dominated by hydrology, the

level of the water table and the timing and duration of flooding, and by the impact of herbivores (CARTER *et al.*, 1978 ;

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MITTSCH *et al.*, 1982; SMITH, 1982; TALLIS, 1983). The nature of the waterlogged environment means that the component flora and fauna have morphological and physiological adaptations which allow them to survive permanent/intermittent flooding, anoxia, the consequent chemical reduction of the soil and, in some cases, high levels of salt (SHANHOLTZER, 1974; DAIBER, 1977; SPEIGHT & BLACKITH, 1983). As a result, wetlands contain species of plants and animals found nowhere else (IUCN, 1964; DAIBER, 1974; SHANHOLTZER, 1974; WELLER, 1981; HOOK *et al.* 1988a). They are also some of the most vulnerable and threatened habitats in Europe and probably the world (IUCN, 1964).

Pattern of use by man

As some of the most productive ecosystems in the world (LEITH & WHITTAKER, 1974), wetland ecosystems have for millennia produced important quantities of food (plant and animal) for people and their livestock, essential materials for thatching (HASLAM, 1973; MALTBY, 1986) and fuel (GRANELI, 1984). Traditional harvesting practices are generally extensive, light and sustainable, so that wild plants and animals co-exist with exploitation by man. As such the ecology of wetlands has been influenced by the impact of man and his livestock, particularly in Europe.

During the past 50 years the use of wetlands has become polarised in the parts of the world with high densities of people, such as Europe. Most wetlands are drained for intensive arable farming or industry (WILLIAMS & HALL, 1987). A number of the remainder have been declared as conservation areas, nature reserves and national parks (IUCN, 1980) and their natural resources are left unused.

The problem

The main aim of protected areas is usually in the conservation of viable populations of wild plant and animal species (MARGULES & USHER, 1981). In many protected wetlands one or a few plant species have tended to become dominant, causing declines in floral and faunal diversity, leading to a reduction in the biological richness of many of wetland reserves since their creation. For instance in the Keoladeo Ghana National Park (India) the fish and bird fauna have declined in abundance following an increase in the cover of introduced aquatic plant grasses *Paspalum distichum* and *Vetivera zizanioides*; the world endangered Siberian cranes (*Grus leucogeranus*) give particular cause for concern (ALI & VUAYAN, 1986). In many other wetlands, particularly in Europe similar, if less dramatic, declines in the abundance and richness of plant and animal communities have been noted, though rarely documented in such detail (but see LECOMTE & LENEVEU, 1986). This trend has also been observed in terrestrial communities (THOMAS, 1960, 1963; WELLS, 1971; BALL, 1974; DUFFEY *et al.*, 1974; JENIK, 1983).

The causes

There are three principal causes of this loss of biological richness of wetlands. In some instances the loss is due to a lowering of the water table either as a consequence of development in the catchment area (dams, irrigation projects...) or of drainage of the land surrounding the wetland. Eutrophication is also a major problem where the wetland is contiguous with intensive agriculture or urban areas (MALTBY, 1986). The third principal cause is succession towards drier habitats dominated by trees and shrubs, called carr (HASLAM, 1973), and to the loss of species of low competitive ability characteristics of early successional stages (BAKKER, 1978). In extreme cases monodominant stands of *Phragmites australis* cover lake edges and marshes; *Salix cinerea* occupies the drier areas and *Halimione portulacoides*, *Spartina townsendii*, *Artemisia maritima* or *Puccinellia maritima* dominate the saltier areas. This succession occurs primarily where there has been a reduction in the traditional uses of wetland vegetation. In the past such uses, especially grazing maintained the parts of the wetland in early successional stages resulting in a mosaic of vegetation communities.

In Europe today traditional uses of wetlands are rarely economically viable. On a much wider geographic scale, wetland reserves have ceased being used by man and livestock for policy reasons (IUCN, 1985), because areas with significant grazing by livestock cannot be included in IUCN's categories I. Strict Nature Reserve, II. National Park or III. Natural Monument (IUCN, 1984).

The solution

The solution to this problem is to slow down, to stop or to reverse the successional processes, at least in some parts of the wetland, in order to maintain the plants and animals of early successional stages and thus the biological richness of the whole area. Techniques which have been used by wetland managers to achieve this include:

- fire
- fire
- herbicides
- cutting
- grazing by large ungulates

The three former options have been discussed elsewhere (NEWBOLD, 1975; BOORMAN, 1977; BEULE, 1979; GANGSTAD, 1986). Grazing as a management tool in wetlands has received little scientific recognition in the past for example, in a recent book *The Ecology and Management of Wetlands* (HOOK *et al.*, 1988b) no mention is made of grazing as a tool in wetland management. This is despite the fact that herbivory has been identified as a major force structuring wetland plant communities (WELLER, 1978, 1979; SMITH, 1982). The lack of recognition of grazing as a management tool is surprising because, it is effective, and unlike the majority of the other management techniques, grazing can produce funds for the maintenance of nature reserves (REIMOLD *et al.*, 1975).

Some forms of domestic animal product from wetlands fetch a high premium. For example, on the Atlantic coast of France the meat of lambs pastured on salt marshes is a delicacy, « agneau de pré salé ».

The ideal strategy is to reintroduce the guild of herbivores which naturally occurred. This is feasible when :

- the wild species can be allowed to recolonise the area either naturally from around, or by reintroduction and
- the animals, once established, will not cause unacceptable damage to human activities in the area surrounding the reserve.

In developed countries where nature reserves are usually small and surrounded by intensive agriculture it will often not be feasible or desirable to re-establish the guild of wild animals. For example, in Europe the larger herbivores (> 200 kg) are extinct, apart from the European bison (*Bison bonasus*) and red deer (*Cervus elaphus*). In these circumstances the only solution is to replace the wild guild with domestic species. The best adapted to wetlands are cattle and horses. These have several advantages over wild animals ;

- they are easy to acquire,
- they can be transported by lorry or train without the need for tranquillisation,
- capture for handling or removal is much easier than with wild animals - they can be contained with cheap fencing,
- their numbers, and therefore their impact, are easier to control

This argument is not universally accepted because overgrazing by livestock can cause widespread and serious environmental damage, which discourages conservationists from using domestic species (OVINGTON, 1984). However, correctly used and managed domestics can play a vital role in the management of ecosystems, particularly ones which have been created by man and his livestock in the past, as in the case of European wetlands.

In this paper we provide a review of the role which grazing can play in the management of the floristic and faunal diversity of wetlands, particularly in Europe.

This review concentrates on the impact of domestic herbivores on wetlands though it is necessary to draw on literature on other species and habitats to illustrate some of the principles.

THE IMPACT OF GRAZING ON WETLANDS

Mechanisms of herbivore/plant interactions

The impact of herbivores on the evolution of plant species and on the structure of vegetation communities has been widely investigated (ELLISON, 1960 ; SPEDDING, 1971 ; CHEW, 1974 ; WATKINS & CLEMENTS, 1978 ; MACMAHON, 1981 ; CRAWLEY, 1983 ; EDWARDS & GILLMAN, 1987 ; MILCHUNAS *et al.*, 1988). Little work has focused on wetlands.

Herbivores have a broad range of effects on plants and plant communities. These can either be selective through the removal of preferred plant species or parts or relatively unselective through trampling, dunging and urination.

The effects of selective grazing can cause notable shifts in the species composition of plant communities (e.g. RAWES 1983). Even the unselective mechanisms can have strong effects : trampling reduces plant cover directly through its effects on the plants themselves or indirectly through its effects on soil structure. Direct effects of trampling include breaking up the litter layer, allowing light penetration and also breaking up living parts e.g. suckers, rhizomes and saplings particularly of plants such as *Phragmites australis* (HASLAM, 1972). Trampling tends to compact the soil leading to a reduction in infiltration rates and aeration of the soil (ALDERFER & ROBINSON, 1947 ; ORR, 1960 ; BRYANT, BLASER & PETERSON, 1972 ; GIFFORD & HAWKINS, 1978). Trampling in the water can lead to a strong increase in the suspended matter in the water column and cause detrimental effects on the growth of submerged plants (DUARTE *et al.*, in press). Trampling has a greater effect on wet clay-based soils and can lead to poaching where the plant material is destroyed and the soil surface churned up (DUFFEY *et al.*, 1974). Poaching leads to a decrease in plant cover and diversity and thus to a degradation of the ecosystem.

The primary impact of herbivores on vegetation is at the level of the individual plant. Through their impact on individuals, herbivores affect the population dynamics of plant species and ultimately the diversity and composition of plant communities (HARPER, 1977).

Effects on individual plants

Grazing can affect every stage of the life cycle of a plant. At each of these stages there is natural selection for those plants which reproduce relatively well in the presence of the herbivores. Herbivores affect plant :

- reproduction,
- dispersal and recruitment,
- growth and survival.

Effects on reproduction

Herbivory reduces fecundity when floral meristems are removed ; and also through defoliation when this reduces the amount of carbohydrate available for seed production. However, some species of plants can compensate by extending the duration of flowering. In this way typically spring-flowering species such as *Iris pseudacorus*, *Caltha palustris* can continue flowering into October (LECOMTE & LENEVEU, 1986).

The reduction in seed number which can result from removal of floral meristems may reduce the population size of a species. Reduced seed size can affect offspring survival through affecting the rate and timing of germination and subsequent seedling growth rate and competitive ability (BLACK, 1957). As a general rule, therefore, herbivory reduces seed number, seed size and offspring survival (CRAWLEY, 1983 ; but see PAIGE & WHITHAM, 1987).

However, grazing can increase strongly the rates of vegetative reproduction in species such as the graminoids whose meristems are inaccessible to the animals (CRAWLEY, 1983).

Effects on dispersal and recruitment

Animals disperse seeds of some species across their feeding range by carrying them and voiding them far from the parent plant (RIDLEY, 1930 ; BULOW OLSEN, 1980 ; JANZEN, 1981 ; BAKKER, DIJKSTRA & RUSSCHEN, 1985). Animals also favour the establishment of young plants by creating regeneration gaps, e.g. hoofmarks and dung patches on which seedlings, particularly of opportunistic species, can grow (CASTLE & MACDAID, 1973 ; GRUBB, 1977 ; HARPER, 1977).

Effects on growth and survival of individuals

The most important aspects of the impact of large herbivores on the growth and survival of individual plants is the removal of plant tissues. Removal of leaves reduces the amount of energy captured by photosynthesis because it reduces the leaf area. However, this negative effect may be mitigated or even overridden by compensatory growth and/or fertilisation by excreta (DETILING & PAINTER, 1983 ; MCNAUGHTON, 1983, 1985 ; SVEJCAR & CHRISTIANSEN, 1987 ; HIK & JEFFERIES, 1990). Removal of buds, meristem and stems can have a much greater impact than the removal of plant leaves because it retards growth and removes more stored energy (e.g. removal of rhizomes of *Scirpus maritimus* by wild boar (*Sus scrofa*)).

Plants of differing growth forms often differ in their susceptibility to defoliation (DAHL & HYDER, 1977 ; ARCHER & TIESZEN, 1980). Most dicotyledonous plants have their meristems high up and these are, therefore, more accessible to herbivores. Most graminoids, on the other hand, like *Scirpus* and *Juncus* spp. are particularly well-adapted to grazing as their meristems are close to the soil surface and are less easily damaged by herbivores. Grasses like *Phragmites australis* have their meristems on elongated shoots and are therefore very vulnerable (HASLAM, 1972).

Dung and urine can kill a plant (MARSH & CAMPING, 1970 ; HARPER, 1977), but they increase nutrient concentrations in the soil by increasing the rates of nutrient recycling, encouraging the growth of plants, especially nitrophilous species. They can therefore be an important component of ecosystem function (BARROW, 1961 ; McLACHLAN, 1971). The distribution of dung and urine can vary considerably depending upon the excretory behaviour of the species involved (PUTMAN, 1986). Cattle drop their dung at random over their feeding range, in contrast sheep and horses defaecate in areas which are distinct from those in which they feed (MARSH & CAMPING, 1974 ; ODBERG & FRANCIS-SMITH, 1976, 1977 ; EDWARDS

& HOLLIS, 1982 ; BAKKER *et al.*, 1983). These behaviours can lead to the redistribution of nutrients between vegetation communities (EDWARDS & HOLLIS, 1982, BAKKER, DIJKSTRA & RUSSCHEN, 1985).

Effects on plant communities, their physical structure, species richness and diversity

The effects of grazing animals on a habitat containing several species of plant involve complex interactions, more suited to analysis by computer than the mind (HARPER, 1977). Predicting the impact of herbivores on plant communities is complicated. There are, however, general rules on the effects of herbivores on plant communities which can assist in the practical management of wetlands.

Grazing is an ecological process which interacts with other processes such as interspecific competition. Its effects differ considerably depending on its intensity, which can range from nil in ecosystems with no grazers to strong in intensive grazing systems. Between these extremes are different levels of extensive grazing systems.

Effects on plant height

Grazing virtually always reduces the overall height of the plant community ; sometimes the effect is a dramatic as a fire. In the Serengeti ecosystem the herds of migrant wildebeest can reduce the height of the Themeda grasslands from over 50 cm to a short even stubble in a week or so (DUNCAN, 1975 ; MCNAUGHTON, 1979). In other cases herbivores such as horses may create a mosaic of heavily grazed patches within tall grass communities (EDWARD & HOLLIS, 1982 ; PUTMAN, 1986). This leads to notable increases in the structural and species diversity of plant communities (RANWELL, 1961 ; BASSETT, 1978 ; JEFFERIES *et al.*, 1979 ; SMITH & ODUM, 1981).

However, the most spectacular effects on the architecture of plant communities are caused by browsers. Trees and shrubs are very sensitive to the effects of the « mega-herbivores » : heavy browsing by elephants can turn bushland into open savanna (KORTLANDT, 1984). Though cattle, goats and horses cannot push over mature trees they do kill individuals of some species by ring-barking. They can also maintain or even create grasslands by limiting recruitment of young trees in wetland (LECOMTE & LE NEVEU, 1986) as well as in upland pasture (LOISEAU & MERLE, 1979 ; MOLENAT, MARTIN-ROSSET & LOISEAU, 1980).

Reduction of cover

Since the height of some plants is reduced, and other plants are killed by herbivores there will usually be a reduction in the aerial parts of plants. The extent of this effect is determined by an interaction between the growth stage of the sward and the intensity of grazing. In lightly grazed, growing swards there may be only a small reduc-

tion in aerial cover, and even increases in basal cover (MILCHUNAS, SALA & LAUENROTH, 1988). In heavily grazed swards aerial cover always declines and basal cover sometimes does so

Effects on species richness and diversity

Grazing can affect the diversity and species richness within a community (α -diversity) in very different ways, it can either increase diversity if the dominant species is preferred or decrease diversity if the dominant species is avoided (LUBCHENCO, 1978). Foraging by herbivores increases the overall structural diversity of a monodominant stand. This results in both an increased variety of communities and increased plant species richness (β -diversity, BAKKER *et al.*, 1983). When grazing is concentrated in small parts of the pasture it creates patches of short vegetation within taller, more lightly grazed vegetation. Patches of short vegetation allow the establishment of less competitive species, especially annuals (GRUBB, 1977; BAKKER *et al.*, 1983). Extensive grazing in winter strongly favours dicotyledonous plants (DUFFEY *et al.* 1974).

When grazing pressure is high then a more homogeneous structure will be created which can lead to a decrease in botanical diversity (KLAPP, 1965; OOSTERVELD, 1975; HARPER, 1977); the replacement of perennials by many annual plants under heavy grazing maintains a α -diversity in some ecosystems (BASSETT, 1980).

For example, in a long term study of salt marshes in north western Holland a few species, *Artemisia maritima*, *Festuca rubra*, *Elymus pycnanthus* come to dominate if grazing by cattle is created (BAKKER & RUYTER, 1981; BAKKER, 1985). As a result the ungrazed areas are generally less species-rich than grazed areas. In the U.K., in salt marshes dominated by *Spartina townsendii* and *Puccinellia maritima* when grazed by sheep, succeed to communities dominated by *Atriplex hastata*, *Phragmites communis* and *Scirpus maritimus* in the absence of grazing (RANWELL, 1961). This successional change occurs in approximately 8 to 10 years. In freshwater wetlands grazing had a marked effect in reducing the dominant species of freshwater marshes, *Scirpus maritimus*, *Phragmites australis* and *Aeluropus litoralis* (BASSETT, 1980). In calcareous communities moderate grazing increases the species diversity of the sward (PETERSSON, 1963; ELYVELAND, 1975). Herbs such as *Liparis loeselii*, *Hammarby paludosa* and *Malaxis monophylla* and several species of mosses which colonise wet bare spots increase in grazed fens because trampling increases the microhabitats favouring their spread (PETERSSON, 1958, 1963; STEEN, 1958; ELYVELAND, 1975, 1978). Grazing favours sedges such as *Carex nigra*, *Flacca* spp. and grasses such as *Deschampsia caespitosa*, *Festuca ovina* and *Agrostis stolonifera* (TYLER, 1984). *Juncus* spp. as also more frequent in grazed areas (JATTINEN, 1950). However important spe-

cies in conservation terms, e.g. orchids, are removed if grazing occurs (LITHEBERG, 1934).

Effects on rates of plant production

Grazing can stimulate or reduce the rate of growth of individual plants (see above): its effects on dryland communities are analogous. However, for wetlands the processes may be different (HIK & JEFFERIES, 1990): further field data are required before generalisation can be made.

In conclusion the effect of herbivory on plant populations are multiple, and vary according to the species and growth stage of the plant. Rates of reproduction are strongly affected by herbivory: seed production declines under heavy grazing, but vegetative reproduction increases in plant species adapted to grazing such as the graminoids. For most species herbivory reduces rates of growth and survival. Except under very heavy grazing, herbivory stimulates the recruitment of young plants.

Grazing affects the architecture of plant communities by reducing the height and cover of aerial parts. This can completely alter the physical structure and the species; composition of the plant communities thus leading to increases in their species richness and diversity except perhaps in extreme cases of overgrazing. By maintaining or restoring the open habitats of early successional stages, grazing allows the conservation of the plant and animal communities of these habitats. In the seasonal wetlands of the Mediterranean region heavy grazing sharply reduces the height and density of invasive emergent macrophytes (DUNCAN & D'HERBES, 1982). This allows the maintenance of early successional stages in these wetlands with dense communities of submerged macrophytes and their associated waterfowl populations.

While the effects of grazing on individual plant species may be detrimental, by increasing species and structural diversity the long-term benefits of grazing to the conservation value of a habitat as a whole may outweigh this. If an important species for conservation is very sensitive to grazing, provision can be made for its protection via small or large scale fencing.

Effects of herbivores on faunal diversity in wetlands

The effects of grazing on the fauna of wetlands has been little studied. Nonetheless two types are evident, direct and indirect effects, through the animals influence on the vegetation.

Of the indirect effects, grazing favours invertebrates, birds and mammals of open habitats but reduces the numbers of species favouring closed habitats; its effects on the species richness and diversity of wetland animal communities have, however, only rarely been measured. Relatively intense grazing maintains the habitat of bird species such as geese and waders; and *Coleoptera* such as Carabids (PUTMAN *et al.*, 1989). It is a common observa-

tion that heavy grazing on dry grasslands causes a strong decline of numbers in small mammals (e.g. PUTMAN *et al.*, 1989); this may - also occur in wetlands.

Extensive light grazing maintains a patchier habitat where zones of short grass co-exist with taller grass and patches of scrub and woodland. Certain groups of flower-loving insects such as Syrphids (*Diptera*) benefit particularly, in terms of species richness and abundance, from extensive grazing (LECOMTE & LE NEVEU, 1986).

The dung of cattle can add considerably to the nutrient and detrital input to wetlands, resulting in elevated fish production (FOX, 1976). Lumbricoid densities were twice as high in grazed plot compared to mowed ones (GRANVAL, 1988).

Grazing to reduce the cover of emergent macrophytes, along with appropriate water management, on the Marais du St. Seren, a freshwater marsh in Tour du Valat, Camargue was followed by a 2.11 fold increase in the number ducks, especially of Teal (*Anas crecca*) and Gadwall (*Anas strepera*) using the marsh as a winter day roost. Care must be taken, however, when grazing is used to improve nesting habitat for birds such as Black-tailed Godwits (*Limosa limosa*), Lapwings (*Vanellus vanellus*) or snipe (*Gallinago gallinago*) as large herbivores may cause nest failure through trampling nests (GREEN 1986, 1988; BEINTEMA & MUSKENS, 1987). In this instance, management policies must incorporate delaying the onset of grazing in order to allow ground nesting birds time to fledge their chicks (GREEN, 1986).

At present the majority of the predictive statements which can be made about the effects of herbivores of wetlands are via the general rules concerning their impact on plant communities diversity and complexity and the habitat requirements of wetland fauna. For example grazers increase the area of open water in reedbeds (DUNCAN & D'HERBES, 1982) thereby encouraging species which use this habitat for resting, feeding (duck and coot) or nesting (grebes).

Of the direct effects, some species of parasites depend totally on the presence of ungulate hosts (e.g. bot flies, warbleflies, *Diptera*) and others such as ticks, *Acarina*, lice, *Mallophaga*, horseflies (*Tabanidae*) are favoured by the presence of large ungulates. Other invertebrates which utilise ungulate dung (MOHR, 1943) and necrophagous species which feed on carcasses have their food supply greatly increased by the presence of large ungulates.

Finally there are commensals which are favoured by large ungulates; Cattle Egrets (*Bubulcus ibis*) follow the large animal and prey on insects and amphibia disturbed by their movements (SIEGFRIED, 1978).

In summary, by maintaining or restoring the open habitats of early successional stages, grazing allows the conservation of the plant and animal communities of these habitats. In the seasonal wetlands of the Mediterranean region heavy gra-

zing sharply reduces the height and density of invasive emergent macrophytes (DUNCAN & D'HERBES, 1982). This allows the maintenance of early successional stages in these wetlands with dense communities of submerged macrophytes and their associated waterfowl populations.

While the effects of grazing on individual plant species may be detrimental, by increasing species and structural diversity the long-term benefits of grazing to the conservation value of a habitat as a whole may outweigh this. If an important species for conservation is very grazing sensitive, provision can be made for its protection via small or large scale fencing

EXAMPLES OF THE USE OF DOMESTIC HERBIVORES IN WETLAND CONSERVATION

In Europe domestic herbivores are increasingly being used to alter wetland vegetation communities for the improvement of bird habitats (DUNCAN & D'HERBES, 1982; DUNCAN *et al.*, 1982; DE BIE *et al.*, 1986; GREEN, 1986; GORDON & DUNCAN, 1988).

In the Camargue, horse grazing in freshwater marshes caused a decrease in the cover of *Scirpus maritimus* and *Phragmites australis* (BASSETT, 1980) creating open water rich in submerged macrophytes such as *Potamogeton pectinatus*. Horses also decreased the height and increased the species richness and diversity of grasslands associated with wetlands (BASSETT, 1980); small annuals (*Bellis annua*, *Hordeum maritimum* and *Parapholis incurvata*) and rosette plants (*Plantago coronopus*) increased in the shorter, open sward.

On the salt marshes of the Dutch Friesland islands, BAKKER and his colleagues (BAKKER, 1978; BAKKER & RUYTER, 1981) have studied the feasibility of using domestic stock to manage abandoned grazing lands. These abandoned pastures are characterized by high litter biomass with a poor species composition. Grazing in these abandoned communities increases the number of plant species in the area by reducing the standing crop of the dominant species and accumulated litter and increasing the openness of the sward. This increased the light penetration and improved germination opportunities.

In northern France the estuary of the Seine River (Parc Naturel Régional de la Brotonne) contains large areas of farmland development at the end of the 2nd World War as part of the Marshall Plan. Much of this has been abandoned and is rapidly being invaded by species-poor willow (*Salix spp.*) dominated woodland and reedbeds. Highland cattle and Camargue horses have been brought in to arrest or reverse this succession. This has been successful, and the species richness of plants and at least some invertebrates is maintained or increasing (LECOMTE & LE NEVEU, 1986).

The Camargue, an island in the delta of the Rhone, is one of the largest wetlands left. In Europe. The landscape

is flat, mostly agricultural in the northern part and along the arms of the Rhone. The rest is lagoons and marshes, ranging in salinity from 330 g/l in the salt pans to less than 0.5 g/l in the freshwater marshes. Salt flats and semi-natural pastures that contain a patchwork of smaller temporary wetlands surround the freshwater marshes. The salt marshes have few plants, but the freshwater and brackish marshes are a mosaic of communities ranging from open water with a well-developed flora of submerged plants to reed beds dominated by the common reed.

Within the freshwater and brackish marshes, cattle and horses determine the structure and composition of the communities of plants. Where they are absent, or scarce, reed beds predominate as do reed-dwelling birds including Bitterns, *Botaurus stellaris*, passerines such as Bearded Tits, *Aegialitis caudatus*, and the predatory Marsh Harrier *Circus argenteus*. Cattle and horses maintain open marsh habitat ideal for many other water-birds; breeding Little Egrets, *Egretta garzetta*, waders on migration, and tens of thousands of ducks and Coot, *Fulica atra*, during winter.

In northern Europe, several conservation groups encourage extensive grazing in wetlands. Britain's Royal Society for the Protection of Birds (RSPB) employs stock keepers on a number of its reserves. On the Ouse and Nene reserves in the washes of east England, RSPB staff currently manage around 1800 head of cattle and sheep between April and November. The RSPB now offers a professionally managed service for farming customers on these reserves. The livestock, owned mainly by private farmers from as far away as Kent and Shropshire, improve the nesting habitat of ducks and waders and provide closecropped pastures for up to 40 000 Wigeon, *Anas penelope*, in winter. At the Loch Cruinart Reserve on Islay, the RSPB has bought a farm where livestock, including 150 of its own cattle, graze to create good quality grass pastures for wintering flocks of Barnacle and White-fronted Geese.

Certain ducks, such as the Shoveler, *Anas clypeata*, and the Pintail, *Anas acuta*, prefer to nest in fields where cattle have grazed previously. Black-tailed Godwits, *Limosa limosa*, and particularly Lapwings, *Vanellus vanellus*, prefer to nest in short, damp grassland which cattle have grazed during the previous summer.

The Wildfowl Trust currently leases out the grazing on its Slimbridge reserve, Gloucestershire and at Caerlaverock on the Solway Firth to manage the visiting geese. At Slimbridge, during the summer and autumn, cattle graze on fields near the public hides. When the geese arrive in autumn, the grazed fields attract them. They gather before the waiting public. At Caerlaverock, cattle and sheep graze on the grasslands during spring and summer, creating the short sward preferred by the Barnacle Geese that winter in Scotland.

CRITERIA FOR THE CHOICE OF DOMESTIC HERBIVORE SPECIES

Because there is little comparative information on the impact of different species of domestic herbivores on wetlands, in the following section we give some generalisations which can be used to infer the likely impact of each species. This approach must be deepened in the future by a rigorous scientific determination of the impact of domestic herbivores on wetland plant communities.

The effect herbivores will have on the communities in which they feed will vary relative to their feeding strategies and habitat selection. This in turn will be determined by their morphology and physiological status (Table 1; VAN DYNE *et al.*, 1980). The species of domestic herbivores available to managers of wetland communities are horses, cattle, and to a lesser extent sheep, goats and geese. The species of domestic herbivore used in wetland conservation will depend upon the type of wetland which is to be managed and the plants manager is trying to control.

Goats are of limited use in wetlands as they are primarily browsers (HOFMANN, 1983). However, goats are less affected by plant secondary metabolites than are the other domestic herbivores and, therefore, may be useful in certain contexts. For example they can be used to eliminate trees and shrubs from pasture (BULLOCK & KINNEAR, 1988). Horses and particularly cattle are relatively unselective grazers (VAN DYNE *et al.*, 1980). Being unselective they can be used to decrease the dominance of grass species and allow an increase in the frequency of dicotyledonous species. Sheep are primarily grazers and are more selective than cattle and horses, so that swards grazed by sheep tend to form a mosaic of short and tall swards with a higher species diversity than those grazed by cattle (SHUPE & BROTHERTON, 1985).

TABLE 1 — Food preferences and foraging strategies of domestic herbivores: + primary; — secondary (adapted from THALEN, 1984).

Préférences alimentaires et stratégies de prise de la nourriture des herbivores domestiques.

	CATTLE	HORSES	GOATS	SHEEP
FOOD PREFERENCES				
Grass & Sedges	+	+	—	+
Rushes	+	+	+	—
Forbs	+	—	+	+
Buds, leaves, twigs	—	—	+	—
FORAGING STRATEGY				
Grazer	+	+	—	+
Intermediate (G/B)	+	—	+	+
Intermediate (B/G)	—	—	+	—
Browser	—	—	+	—

Cattle are more useful in controlling *Typha* spp. than are horses as the latter are unwilling to eat this species, (P. DUNCAN, pers. obs.) presumably because it contains toxic secondary compounds. Cattle are the most-effective species for controlling *Phragmites australis* as they are relatively unselective and will graze deeper into the reed bed during the growing season than will other species (HASLAM, 1968). Goats and horses tend to consume only the upper portions of new shoots, whereas sheep graze *Phragmites australis* only during the spring. WILLIAMS (1959) has shown that the effectiveness of cattle in controlling salt marsh vegetation can be improved by providing walkways. These improve the accessibility of parts of the marsh which would otherwise remain ungrazed; they also provide refuges during high tide.

Depending upon the management goals, trampling can be either detrimental or beneficial in wetland ecosystems. Trampling also tends to break up the subterranean rhizomes of plants such as *Phragmites australis* killing the plants (HASLAM, 1972). Hoofmarks may also act as germination sites (HARPER, 1977). If control of species with underground rhizomes is the main aim then cattle, which have eight hooves and tend to be the most effective domestic species to use (HASLAM, 1968). In contrast, if the damage caused by trampling is to be minimized then sheep, which have low tread pressures, will be the ideal management tool.

The breed of animal used will also be an important consideration when the plants are unpalatable or living conditions difficult. For example, when control of *Spartina townsendii* in salt marshes is the management goal then old breeds of sheep must be used; modern breeds find this species unpalatable (RANWELL, 1971). In general, breeds adapted to the local environment are the most appropriate to use in management for nature conservation. The reconstructed wild cattle (hecks) and tarpans (koniks) of northern Europe have curiosity value but there is no evidence that they are genetically closer to the extinct wild animals than local breeds. It is likely that hardy breeds such as the Highland cattle, or Exmoor ponies would survive in conditions where the reconstructed breeds would die.

If animal products are to be marketed then great care must be taken in their choice and management. For example the milk of dairy cattle is said to be tainted when these animals graze certain types of saltmarsh (JACQUET, 1949).

MANAGEMENT SYSTEM

The most widespread management system in pastoral areas is continuous grazing, where the range is a single unit and the animals use it year-round. There are more complex rest-rotation systems which have been developed to raise animal performance e.g. short duration, H.L.L.F. (high in-

tensity - low frequency), or Merrill and are not always successful in achieving their objective. These systems are not generally of interest per se to managers of nature reserves whose management objectives do not focus on animal production (see also HOLECHEK *et al.*, 1987).

For nature reserves continuous grazing is an ideal system because it does not involve costly investment in fencing and requires minimal manipulation of the animals, which is risky and costly in manpower. The disadvantage is that within the limits of the stocking rate, the animals, not the manager, determine the timing, location and intensity of their impact on the plants. For some larger nature reserves the management objectives can be achieved by a continuous grazing system with a carefully chosen site of animal species, and an appropriate stocking rate. The choice made will depend upon the management goals and the ecosystem under consideration (Table II). In upland bogs, fens and mires a low stocking rate will maintain plant diversity; higher rates will tend to decrease the diversity of these habitats and encourage dominance of *Eriophorum vaginatum* (RAWES & HOBBS, 1979). On the other hand marshes can sustain quite high levels of utilization by herbivores. British salt marshes are said to be able to support 5-7 sheep per ha when free of tides (RANWELL, 1972) and *Phragmites/Scirpus* marshes in the Camargue up to 0.7 horses per ha over the 150 day grazing season (DUNCAN & D'HERBES 1982). In general, the wetland ma-

TABLE II — Typical stocking densities (animals/ha) of domestic herbivores on wetland habitats: * stocking densities considered to have a significant detrimental impact on the vegetation community. Data from WILLIAMS, 1955; WELCH & RAWES, 1966; RANWELL, 1972; GRANT *et al.*, 1976; BEEFTINK 1977 a-b; RAWES & HOBBS, 1979; DUNCAN & D'HERBES, 1982; JENSEN, 1985.

Densités typiques (animaux/ha) d'herbivores domestiques en zones humides: * densités considérées comme ayant un impact significatif sur la communauté végétale

Salt marsh	sheep: 4.5-6.5, 5.7.5; 0.5-3; 5-7; 0.5 cattle: 0.62-1.25; 0.33-0.5; 1.3-1.7*; 0.65; 0.5 horses: —
Freshwater marsh	sheep: — cattle: 0.3-3 horses: 0.2-0.5
Blanket bog	sheep: < 0.4, 0.44; 0.37, > 0.55*, 2.2*; < 1 cattle: — horses: —
New polder	sheep: 0.27 cattle: — horses: —

nager must set a desired state which he wishes to achieve, in terms of plant community or plant species diversity, sward structure and/or indicator species presence or absence. The stocking density can then be adjusted until the desired state is reached.

Because animals feed selectively, a continuous grazing system usually results in heavy use of a small number of communities in the ecosystem (HUNTER, 1962; DUNCAN, 1983; PUTMAN 1986 GORDON 1989). At low stocking densities this can result in intensive use of a few communities with very little use of others; continuous grazing will therefore lead to some spatial variations in animal pressure, and thus in plant structure and species composition, especially if horses are used. These animals often turn homogeneous pastures into patchy ones by grazing certain areas very short and using others as « latrine areas » (ODBERG & FRANCIS-SMITH, 1977; EDWARDS & HOLLIS, 1982).

However, in many cases the natural foraging patterns of the animals will not lead to the spatial and temporal variations in grazing pressure needed to achieve the management objectives. It will then be necessary to impose a pattern on the animals' use of the range.

Spatial patterns

These can be enhanced by appropriate subdivision of the wetland into management units using rivers, canals or fences (c.f. DUFFEY *et al.*, 1974). Some of these units can be completely protected from grazing, e.g. to encourage woodland and *Phragmites* reedbeds, while others can receive different stocking rates to maintain communities of short emergent macrophytes or open water.

Temporal variation

As a general principle the greatest effect of herbivores on plants is achieved by grazing during the season when the plants are growing strongly, because the animals remove photosynthetic tissue and thus reduce the size of the plants and the rate at which nutrient reserves are reconstituted. Spring and summer grazing will have a major impact on the plant communities present in wetlands. During this time the plants' growing points are most susceptible to grazing. This is especially true of *Phragmites australis*: control of this species is most effective where the growing shoots are bitten off and then the area is flooded so that the damaged shoots lie below the water surface, causing them to rot and die (HASLAM, 1973). Grazing during the summer will reduce the quantity of flowers and seeds produced (DUNCAN & D'HERBES, 1982), favouring species with vegetative reproduction (i.e. *Phragmites australis*, *Scirpus maritimus*) and will select against annuals invading a pasture.

Winter grazing reduces the standing crop, especially of perennial plants because the herbivores avoid annuals and geophytes, whose aerial parts are dead in this season.

PLANNING, MONITORING, MANAGEMENT AND FUTURE RESEARCH

Prior to any use of domestic herbivores of wetland conservation three important factors must be considered: i) whether domestic herbivores would be the best tools for management under the particular circumstances [the upland bogs and mires are particularly sensitive to trampling (GRANT *et al.*, 1985) domestic herbivores are therefore of limited use in maintaining these ecosystems]; ii) which species or combination of species of domestic herbivores would be best serve the conservation objectives; and iii) which grazing management regime (i.e. stocking density and duration and timing of grazing) should be used.

The problems of overgrazing in areas where livestock have simply been released and abandoned are well known. When used for wetland management the herds must be under the effective; planned control of the manager.

Monitoring and fine tuning

Evaluation and fine tuning of management requires monitoring. This should be initiated prior to the new management regime being implemented, should be detailed enough to evaluate the success of the management, and should provide early warning of problems of overgrazing.

Future research

There remains a great deal to discover about the interactions between domestic herbivores and wetland ecosystems. Perhaps the most important gap is the effects, indirect and direct, of grazing on the animal communities, especially invertebrates and fish.

More specifically, there is little quantitative information on species and breed differences in impact on wetland plant communities. It would be very valuable to have a set of comparable studies where different breeds of cattle, or horses, were run together and measurements made of: - their effect on population dynamics of threatened species of plants and animals; - their feeding and ranging behaviour, diets, body condition and survival, rates of liveweight growth.

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UNDER-UTILIZATION AND INTENSIFICATION IN TWO BRITTANY WETLANDS*

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KEY WORDS : France, Brittany, wet grassland, marsh, under utilization, intensification, mapping.

RÉSUMÉ

SUMMARY

DÉPRISE ET INTENSIFICATION DANS DEUX ZONES HUMIDES DE BRETAGNE.

Pour mettre en évidence les relations entre sol, végétation et quantité d'eau, deux zones humides à usage agricole ont été étudiées en Bretagne à deux échelles différentes, parcelle et petite région naturelle.

- la parcelle est une prairie humide presque abandonnée parcourue par un ruisseau et délimitée par une haie.

- la petite région naturelle est un marais complexe qui après une phase d'abandon a été soumise à un aménagement hydraulique puis valorisée par du maïs.

En comparant les cartes établies, on observe une concordance entre les principales communautés végétales hygrophiles, les sols hydromorphes ou tourbeux et les zones saturées en eau. Toutefois l'usage agricole plus ou moins intensif se traduit par des modifications de flore : communautés rudérales en milieu piénié, envahissement par les ligneux en cas d'abandon, champs de maïs et régression des héliophytes suite aux aménagements hydrauliques. Sur le marais, six ans après les récupérations de parcelles, des signes de trop grande humidité sont à nouveau manifestes.

In order to show the relation between soil, vegetation and hydrology, two agriculturally exploited wetlands in Brittany were studied on two different scales : a plot and a small natural unit :

- the plot is a nearly abandoned wet grassland with brook running through it, surrounded by a hedge.

- the small natural unit is a complex marsh which, after having been abandoned, underwent hydraulic work and was then valorized by maize crops.

By comparing their charts, we observe concordance between the main hygrophilous plant communities, waterlogged soils or peatland. However, more or less intensive agricultural use modifies plantlife : ruderal communities in trampled areas, shrubs* in abandoned areas, maize fields and regression of heliophytes following hydraulic works. Six years after the recuperation of the plots on the marsh, there are once again signs of too much humidity.

INTRODUCTION

In Brittany, wet grasslands and marshes previously formed an integral part of the various crop and animal production systems functioning as complementary fodder producing areas. Recent agricultural development has led to either the abandoning of these wetlands, or their draining and use for intensive maize cropping. Both situations are presented here :

1) On a plot, at one hectare scale, an underused meadow was investigated. We intended to point out the relationships between the topography, the frequency and the localization of saturation, the soil units and the plant communities.

2) On a small natural unit, of almost 100 hectares, we studied the changes brought about by hydraulic management of wetland in soil valorization and in vegetation.

STUDY AREAS

The grassland of Kerhoeh (2°56' long., 48°00' lat.) is located in the Commune of Naizin, 12 km south-east of Pontivy. It is elongated in shape, covering 3.9 ha, with a brook running through it. Fences and hedgerow mark the boundaries of previous small plots. The meadow is used

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for low density pasturing of cattle (0.4 cow per ha).

The marsh of Renac (1°58' long, 47°43' lat.) is located 10 km north-east of Redon. This wetland includes a pond, marshes, and wet grasslands, covering altogether over 60 ha. Currently abandoned, it was used until 1950 for grazing and poor fodder cropping. Helophyte stands and peaty woods grew and collapsed into the stream, leading to flooding of the upstream meadows, since the difference in level between lower and upper zones is about 1 m. This submersion became more marked with the increase in peak flow discharge following removal of shelterbelts in the upper part of the river basin (MÉROT, 1978). During land reclamation processes, stream management was decided and an ecological report was made (HAURY & RIVIERE, 1982). Four years after the main work, a map of vegetation was produced (LABAUME, 1985).

METHODS

Maps have been drawn to assess the relationships between soil, vegetation and moisture.

- In Kerhoeh grassland, where the relief is smooth, the soil moisture ranges from values close to field capacity to values reaching saturation, with the occurrence of ponding water. These areas were charted according to ground based survey at different dates throughout the winter of 1986-1987, as part of a study on the dynamics of the variable source areas (BRUN *et al*, 1990).

- Topography was studied in the grassland with a surveyor's rod and a theodolite, following a regular sampling plan.

- Soils were investigated by drilling holes down to 50 cm, minimum depth. The characteristics described were horizon and soil depth, colour (according to Colour Chart Munsell), parental materials, hydromorphic classes, estimated percentages of oxidized and reduced volumes, concretions, stones and the number of roots per cm², and leaching. The soils were classified according to Soil Taxonomy (SOIL SURVEY STAFF, 1975). In the Kerhoeh grassland, observations were based on a regular sampling plan. In the Renac marsh, bore-hole observations were located at any vegetation change. Soil typology was done by manual data clustering.

- Vegetation was investigated using phytosociological observations on units of 16 m² in the grassland, and on units of 16 m² to 100 m² in the marsh. Complementary phytosociological surveys were made when obvious change occurred. Using the phytosociological data from the Kerhoeh grassland, a Factorial Correspondence Analysis gave the hierarchy of ecological factors; Principal Component Analysis and Hierarchical Ascending Classification were subsequently used to emphasize grassland types.

RESULTS

Kerhoeh grassland

Topography and hydrology - The maximum difference in level over the meadow is 5 m. The topographic map (FIG. 1) shows a small plateau downstream, where the slope lines diverge. On figure 2, the boundaries of the saturated areas have been drawn for 3 dates : in February 1987, the whole meadow was flooded, except for a small area on the plateau ; during the month of March, the saturated zone shrank especially around the plateau (the diverging zone) and in the upstream part of the meadow. The remainder of the plot was submerged all winter long. The dynamics of the saturated areas is therefore directly related to the topography.

Pedology - Seven soil types have been identified and mapped (FIG. 3) from 100 observations. At the entrance of the plot, allogeneous materials form an anthropic umbrept. Along the brook, the soil is a cumulic fluvaquent. Within the lower parts of the plot, soils are more and more hydric. Soils on the south-western plateau are umbraqualf and glossaqualf.

Vegetation - For the grassland typology, 169 surveys and 77 species were considered. Six main grassland types have been defined using multidimensional analysis (FIG. 4). Their development is firstly governed by land utilization and trampling (« ruderalisation ») (communities including *Plantago major* and others dominated by *Polygonum hydropiper*) and secondly by plot moisture (4 further types) : on the second axis of Factorial Component Analysis, the species are ordinated according to their hydrophilous trend (PÉRONNE, 1987).

Renac marsh

Soil and vegetation before management

Soil - With 87 observations, 3 types have been distinguished (FIG. 5). The fluvaquent soils are associated with alluvial materials. Intergrade ones, between aquents and hemists, are mineral soils with organic horizons corresponding to peaty vegetation. The soils resulting mainly from marsh plant detritus are medihumist; these soils may sometimes float at the boundary of the pond.

Vegetation (FIG. 6) - The flora includes oligotrophic and dystrophic species (such as *Potamogeton polygonifolius*, *Scirpus fluitans* and *Hypericum elodes*) and eutrophic species (such as *Elodea canadensis* and *Sparganium emersum*) : CLÉMENT (1986) calls this type of area a « complex wetland ». Before management wet grasslands (*Glyceria fluitans*) were localized on the fluvaquent soils, helophyte stands dominated on intergrade soils, and peaty woods developed on medihumist soils. The small size of aquatic areas was obvious.

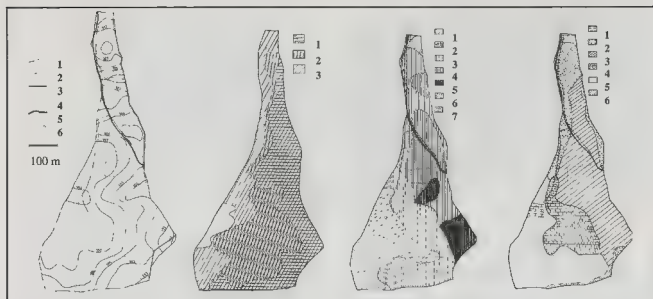


FIG. 1 — Kerhoeh : Topographic map.
1 : contour lines ; 2 : hedges ; 3 : permanent-fences ; 4 : fences ; 5 : brook ; 6 : tramp.

Kerhoeh : topographie
1 : courbes de niveau ; 2 : haies ; 3 : clôtures permanentes ; 4 : clôtures ; 5 : ruisseau ; 6 : cheminement du bétail

FIG. 2 — Kerhoeh : Extension of the saturated area at three dates.

1 03/20 ; 2 03/03 ; 3 02/27
Blank area has not been saturated during the winter

Kerhoeh : extension de la zone saturée à trois dates
1 : 03/20 ; 2 : 03/03 ; 3 : 02/27

FIG. 3 — Kerhoeh : Soil map

1 : anthropic umbrept ; 2 : cumule fluvaquent ; 3 : lightly hydric ; 4 : hydric ; 5 : strongly hydric fluvaquent ; 6 : umbragualf ; 7 : glossaqualf

Kerhoeh : carte des sols.

1 : sol d'apports anthropiques ; 2 : sol alluvial ; 3 : sol faiblement hydromorphe ; 4 : sol hydromorphe ; 5 : sol alluvial fortement hydromorphe

FIG. 4 — Kerhoeh : Vegetation map.

1 : ruderal zone ; 2 : *Polygonum hydropiper* communities ; 3 : hygrophilous grassland ; 4 : meso-hygrophilous grassland ; 5 : mesophilous grassland ; 6 : grassland with hedge species.

Kerhoeh : carte de végétation.

1 : zone rudérale ; 2 : communautés à *Polygonum hydropiper* ; 3 : prairie hygrophile ; 4 : prairie mésohygrophile ; 5 : prairie mésophile ; 6 : prairie avec espèces des haies

Management results

The process was carried out in 2 stages : the digging of a lateral ditch caused a 0.5 m water sheet level decrease within the upper system ; following this, the dredging of the River Canut, across the marsh, led to a further 0.5 m decrease.

Three types of agricultural improvement occurred. They were from downstream to upstream :

- on intergrade soils, a wetland clearing by helophyte cutting or burning, with localized *Trifolium repens* over-seeding,

- on alluvial soils, a change of *G. fluitans* grasslands, with repetitive cutting and grazing, towards hygrophilous and varieted meadow with rushes (*Juncus effusus*),

- mainly on alluvial soils and on some close intergrade ones, arable land constitution by deep ploughing and maize seeding.

On unused areas, helophytes decreased, especially *Typha latifolia*. In water, eutrophic species increased so as to cover almost the whole pond which was in the process of filling up with sediments, and *Ceratophyllum demersum* appeared. Simultaneously, oligotrophic and dystrophic species decreased.

DISCUSSION

Relationships between hydrology, soil and vegetation

Topography governs saturation and soil distribution. Most plant communities also reveal general moisture, and some can form peaty soil. So close relationships appear between hydrology, soil and vegetation in undisturbed or extensively used systems (as in the Renac marsh before management and the low parts of the Kerhoeh grassland), specially in the wettest areas.

Nevertheless, particularly in the Kerhoeh grassland, the vegetation has been selected by the uses of the land. On one hand, in some confined areas, a vegetation « wetter » that it should be according to the soil, can appear in confined cattle areas (plateau fence) or tramp (with *P. hydropiper*) : this poor meadow use could appear on the pedological map, if a soil surface analysis was carried out. On the other hand, in the south fence, the vegetation of this former field is clearly « drier » than the soil shows and a crop weed species, *Agropyrum repens*, grows. The invasion along the hedges, but also in the middle of the meadow, by *Salix* sp. (willow) and *Rubus* sp. (bramble) shrubs indicates underuse and natural tendency to willow copse.

An evaluation of Renac development

The benefit from current development is low, because the slope is too weak for good stream drainage. So maize growing on intergrade soils poses problems of crop health : downy mildew due to *Sclerospora macrospora* (a disease restricted to wet areas), competition with marsh weeds, and perhaps sensitivity to aluminium (3 meq/100 g of Jackson Aluminium in ploughed horizon). Maize cropping is difficult in a wet autumn. In the meadows, invasion by *Iris pseudacorus*, *J. effusus* and *Carex sp.* indicates a relative failure of management, which can be explained by the water level increase in the lower part of the marsh.

CONCLUSION

In these systems, cyclic and linear variations appear :

- the annual cycle of saturation and unsaturation is materialized either by the soil units or the main plant communities ;
- three stages in the evolution are shown by the soil and mainly by the vegetation : past uses (ploughed horizon, remaining weeds), present features (ruderal process, maize cropping), foreseeable changes (invasion by shrubs).

As the saturation of the soils depends mainly on the topography, when the water level is poorly controlled due to landscape conditions, land exploitation remains difficult.

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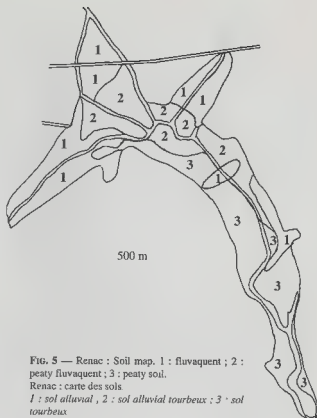


FIG. 5 — Renac : Soil map. 1 : fluvaquent ; 2 : peaty fluvaquent ; 3 : peaty soil.
Renac : carte des sols
1 : sol alluvial, 2 : sol alluvial tourbeux ; 3 : sol tourbeux

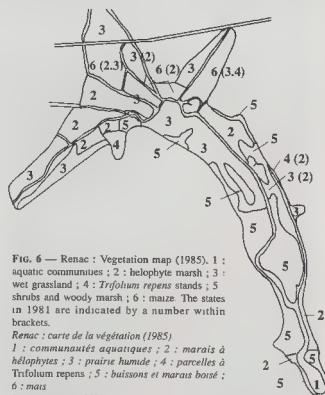


FIG. 6 — Renac : Vegetation map (1985). 1 : aquatic communities ; 2 : helophyte marsh ; 3 : wet grassland ; 4 : *Trifolium repens* stands ; 5 : shrubs and woody marsh ; 6 : maize. The states in 1981 are indicated by a number within brackets.
Renac : carte de la végétation (1985)
1 : communautés aquatiques ; 2 : marais à hélophytes ; 3 : prairie humide ; 4 : parcelles à *Trifolium repens* ; 5 : buissons et marais boisé ; 6 : maïs
La situation en 1981 est indiquée par un chiffre entre parenthèses.

PHYTOGEOGRAPHICAL ORIGINALITY AND CONSERVATION OF PEAT BOGS OF « PAYS DE BITCHE » (Northern Vosges Mountains, France)*

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MOTS CLÉS : Tourbière, phytogéographie, conservation, Massif Vosgien.

KEY WORDS : Peat bog, phytogeography, conservation, Vosges Mountains.

RÉSUMÉ

ORIGINALITÉ PHYTOGÉOGRAPHIQUE ET CONSERVATION DES TOURBIÈRES DU PAYS DE BITCHE (VOSGES DU NORD, FRANCE).

Les tourbières du Pays de Bitche sont marquées par la présence de groupements végétaux primaires à affinité continentale, d'un grand intérêt biogéographique.

L'ingérence humaine dans ce milieu depuis plusieurs siècles s'est traduite par le recul de cet élément continental relictuel au profit de groupements végétaux secondaires, présentant des affinités atlantiques très marquées.

Le maintien de la richesse et de la diversité de ces groupements secondaires a nécessité la mise en place de modes artificiels de gestion conservatoire (comme des variations saisonnières des plans d'eau). Une telle intervention a ainsi permis la réapparition massive de *Rhynchospora fusca* et *Lycopodiella inundata* dans un site où ils n'avaient plus été observés depuis une dizaine d'années.

SUMMARY

The peat bogs of the Northern Vosges Mountains are characterized by the presence of primary plant communities with continental affinities of great biogeographical interest.

Human interference, which has been going on for several centuries in these surroundings, has induced the retreat of this relictual continental element to the benefit of secondary plant communities with atlantic affinities.

The preservation of the richness and the diversity of the secondary groups has shown the need to plan artificial conservation measures (such as seasonal variations of the water level in pools). Such an enterprise has permitted the massive reappearance of *Rhynchospora fusca* and *Lycopodiella inundata* on a site in which they had not been seen for about ten years.

INTRODUCTION THE REGION AND ITS PEATLANDS

The Pays de Bitche, in the Northern Vosges Mountains, is composed of a complex of geomorphological depressions, between 250 and 300 m altitude, in the Vosgian sandstone. It is more than a hundred meters lower than the western border of the Plateau of Lorraine which reaches a height of 400 to 420 m. This setting results in a particularly harsh climate with minimum temperatures more than 1.5°C lower in winter and 3-4°C lower in summer than on the Plateau Lorrain and in the north of the

plain of Alsace. The lowest points of the depressions in the Pays de Bitche are frequently occupied by peat bogs, favoured by the climate and the siliceous substrate.

Unfortunately practically all these peatlands have been subjected to varying degrees of human interference (creation of fishponds since the Middle Ages, drainage operations, planting with spruce...). These activities have greatly disturbed the primary vegetation of the peat bogs and brought about the disappearance of several remar-

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kable species, which were recorded in the last century by SCHULTZ (1846).

At the same time these modifications have had positive effects by creating new habitats (lake shores with variable water levels, peaty moorland, areas of bare peat) which have permitted the establishment of secondary vegetation adapted to the new conditions.

METHODS USED FOR THE PHYTOSOCIOLOGICAL STUDY

The vegetation has been analysed using the stigmatic method (GUINOCHE, 1973). A hundred samples were taken in the different peatlands of the area. Statistical treatment of the data (by factorial correspondence analysis) has shown the existence of 13 groups of samples (MULLER, 1986). Comparison with the literature showed them to belong to 6 different plant associations, each composed of several sub-units (sub-associations and variants). Among these associations, three belong to primary vegetation groups and the three others to secondary habitats created by human activities.

PLANT ASSOCIATIONS OF THE PEATLANDS OF PAYS DE BITCHE

THE PRIMARY PLANT ASSOCIATIONS

The floating raft vegetation : *Caricetum lasiocarpae**

This association, which represents the initial stage of peat bog formation in the Pays de Bitche, is characterized by pioneering species such as *Carex lasiocarpa*, *C. rostrata*, *Comarum palustre*, *Eriophorum angustifolium*, *Menyanthes trifoliata* and, less frequently, *Calla palustris*. Two sub-associations occur:

- an « acidocline » sub-association, differentiated by *Sphagnum inundatum*, *S. subsecundum*, *Drepanocladus exannulatus*... The pH is close to 6 and the raft still very fragile,
- an « acidophile » sub-association, differentiated by *Sphagnum fallax*, *S. papillosum*, *S. palustre*, etc. This vegetation type follows the latter in the ecological succession. It corresponds to a more marked acidification of the water (pH varying from 5.5 to 4) and definite thickening of the floating raft.

The ombro-soligenous peat bog association : *Sphagnetum magellanicum*

This association is characterized by the dominance of acidophilous *Sphagnum* species, *Sphagnum magellanicum*, *S. rubellum*, and *S. fallax*, accompanied by *Drosera*

rotundifolia, *Vaccinium oxycoccos*... Two sub-associations have also been observed :

- * a sub-association of *Sphagnum papillosum*, *Rhynchospora alba*, *Dactylorhiza traunsteineri* and several transgressives of the *Caricetum lasiocarpae*, from which this vegetation type evolves,
- * a sub-association of *Eriophorum vaginatum*, *Vaccinium uliginosum* and *Andromeda polifolia*, showing a more advanced stage of development of the peat bog, as it is colonized by different woody plants (*Pinus sylvestris*, *Betula pubescens*, *Frangula alnus*...).

The pine forest peat-bog : *Vaccinio Uliginosi-Pinetum*

This association is characterized by the constant presence of *Vaccinium uliginosum*, accompanied by various species of *Sphagnum* (*Sphagnum magellanicum*, *S. nemoreum*, *S. parvifolium*, *S. palustre*) and species from coniferous forests of *Vaccinio-Piceetum* and *Dicrano-Pinion* (such as *Vaccinium myrtillus*, *Dicranum polysetum*, *Ptilium crista castrensis*, etc). They follow the *Sphagnetum magellanicum* in the natural dynamics of the peat bogs of the Pays de Bitche and form their terminal stage. The Scots pine is indigenous (MULLER, 1985a).

THE SECONDARY PLANT ASSOCIATIONS

The amphibious association on peaty sand : *Eleocharitetum multicaulis*

This group is characterized by *Eleocharis multicaulis* and *Potamogeton polygonifolius*, with which are associated various species of the class *Littorelletea uniflorae*, such as *Juncus bulbosus*, *Elatine hexandra*, *Myriophyllum alterniflorum*. They occur in the amphibious zone at the edge of water bodies with varying water levels on sandy alluvium.

The vegetation of wet peaty sand and bog pools : *Sphagno-Rhynchosporietum*

This association is well characterized in the Pays de Bitche by *Drosera intermedia*, *Rhynchospora alba*, *R. fusca*, *Lycopodiella inundata*.

Two sub-associations have been observed :

- * a sub-association differentiated by *Sphagnum auriculatum*, *S. inundatum* as well as transgressives from the *Eleocharitetum multicaulis* (*Eleocharis multicaulis*, *Juncus bulbosus*, etc). They colonise the edges of water bodies with fluctuating water levels and follow the *Eleocharitetum multicaulis* in the natural filling of these ponds by sedimentation,
- * a sub-association differentiated by the abundance of *Sphagnum cuspidatum* and by the absence of *Rhynchospora fusca* and *Lycopodiella inundata* as well as the species which differentiate the first sub-association.

* Nomenclature of bryophytes according to CORLEY and al (1981), of vascular species and plant associations according to OBERDORFER (1983).

tion. This community probably results from the impoverishment, due to human interference, of initial communities of *Caricetum limosae*.

Peat moorland :

Juncetum squarrosi sphagnetosum compacti

This association is dominated by heather and purple moor grass, accompanied by fen species (*Juncus squarrosus*, *Pedicularis sylvatica*, *Gentiana pneumonanthe*...) and species from active peat bogs (*Drosera rotundifolia*, *Eriophorum vaginatum*). It is characterized by *Sphagnum molle*, *S. compactum* and *Cladopodiella francisci*.

A remarkable variant appears on denuded peat surfaces. It is differentiated by *Lycopodiella inundata* and several other species of the *Sphagno-Rhynchosporium* (*Drosera intermedia*, *Rhynchospora alba*...).

BIOGEOGRAPHICAL AFFINITIES OF THESE ASSOCIATIONS IMPACT OF HUMAN ACTIVITIES

The three associations related to the natural dynamics of the vegetation (*Caricetum lasiocarpae*, *Sphagnetum magellanici*, *Vaccinio uliginosi-Pinetum*) show boreocontinental biogeographical affinities as indicated by distribution maps of these groups (FIG. 1a, 1b et 1c). Thus the *Vaccinio uliginosi-Pinetum*, climax of peat bogs of the Pays de Bitche, reaches the western limit of its range here.

This continental element of peatland vegetation is regressing. It is particularly clear for the most aquatic peatland groups, which appear to be the most vulnerable to human disturbance. One can also note the disappearance of *Carex diandra* and *Eriophorum gracile* from the *Caricetum lasiocarpae*, two species which were present during the last century (SCHULTZ, 1846 ; MULLER, 1985b). In the bog pools (« Schlenken ») which form mosaic shaped depressions in the *Sphagnetum magellanici*, it is no longer possible to find *Scheuchzeria palustris* and *Carex limosa*, which explains the disappearance of the *Caricetum limosae* from this region.

On the contrary, the secondary plant communities, favoured by human activities (*Eleocharitetum multicaulis*, *Sphagno-Rhynchosporium*, *Juncetum squarrosi*), show biogeographical affinities which are clearly atlantic (FIG. 1d, 1e et 1f). This is very marked for the *Eleocharitetum multicaulis*, which reaches its eastern limit in the Pays de Bitche and the Lusatia in Germany.

These secondary groups, with atlantic affinities, are still in a phase of extension. Thus *Eleocharis multicaulis*, present now at four sites in the Pays de Bitche (MULLER 1985b), probably did not exist there 150 years ago, at the time of SCHULTZ. Neither was *Sphagnum molle* mentioned by SCHULTZ and could equally be a recent arrival

(MULLER, 1985c). It also seems probable that *Erica tetralix*, discovered recently in two peat bogs at the edge of Scots pine plantations, has arrived in this region in the last 50 years (MULLER, 1985b).

Therefore human interference in the peatlands of the Pays de Bitche results in progressive substitution of the relict continental element of the flora by an element with marked atlantic affinities. The regression of the former can also be observed in other habitats (forest, hedges, heaths, grasslands with therophytic plants...). It thus registers a general retreat of the continental element of the flora of the Pays de Bitche.

METHODS OF CONSERVATION OF THE SECONDARY ASSOCIATIONS

The dynamics of primary peat bogs is extremely slow, at a rate of centuries or more. Conservation management of these does not appear necessary, although the creation of artificial ponds in the Middle Ages probably induced the revival of initial stages at several sites.

On the contrary, the secondary associations, produced by human activities, require appropriate management to ensure their survival.

Thus the *Eleocharitetum multicaulis* and the *Sphagno-Rhynchosporium sphagnetosum auriculati* are adapted to the seasonal fluctuations of water level in the water-bodies around which they grow. Any modifications in the hydrodynamic regime can provoke rapid changes in the flora. To obtain the full development of these two associations, applying artificial water fluctuations of correct amplitude (about 40 cm, with high water from November to April and low water from May to October) is necessary. Such ecological management applied from 1982 onwards to the « étang de Lieschbach » allowed the massive reappearance as soon as 1985 of *Rhynchospora fusca* and *Lycopodiella inundata*, two species which had not been seen since 1978, following years of heavy rainfall and a water level kept too high at the end of the 1970s.

The peaty heathlands of *Juncetum squarrosi sphagnetosum compacti*, resulting from drying and deforestation of peaty zones, do not seem to be very dynamic in the Pays de Bitche (as a paraclimax), and do not require any management. On the contrary, its initial stage of *Lycopodiella inundata*, which follows the exposure of the peat by the removal of the top soil, is cicatrized in about ten years. To preserve this initial stage, rich in *Lycopodiella inundata*, therefore requires a periodic exposure of parts of the peat surface. On the military training grounds close to Bitche, where this association occurs, the craters from the explosion of shells and the ruts made by the occasional passing of military vehicles are sufficient to maintain this initial stage, as is shown by the abundance of *Lycopodiella inundata*.



FIG. 1 — European distribution maps of the six main plant associations of peat bogs of « Pays de Bitche ». Aire de répartition européenne des 6 principales associations végétales des tourbières du Pays de Bitche

In order to determine the rate and precise manner of the floristic changes in the secondary habitats, we have set up permanent quadrats, during the summer of 1988, in order to follow the vegetation dynamics over a long period.

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Preliminary Announcement of the

6th European Ecological Congress

*Organised by European Ecological Federation and Société Française d'Ecologie
Marseille, France, September 7th to 11th, 1992*

This is the 6th European Ecological Congress but the first organised under the auspices of the European Ecological Federation which was established in March 1990 by Ecological Societies throughout Europe to promote cooperation within the Science of Ecology. The Congress will have a new format and involve both morning Plenary sessions, with invited speakers and contributed papers, and afternoon parallel sessions of contributed papers and poster sessions on a wide range of topics.

-The Plenary session themes are :

1. Urban impacts on ecosystems
2. Ecological genetics and behavioural ecology
3. Ecological risk
4. Ecological basis for biodiversity conservation

-The range of topics suggested for the afternoon sessions include :

- Ecological constraints and life history strategies of plants and animals
- Genetics, dynamics and modelling of populations in fragmented habitats
- Ecosystem dynamics, landscape changes and human impact
- Impact of afforestation on natural ecosystems
- Disturbance
- Integration between the physical environment and communities
- Theoretical approaches to ecology and case studies
- Dynamics and heterogeneity
- Environmental risks of biological control and genetically engineered organisms
- Microbial ecology
- Bioenergetics and trophic behaviour

The organisers would welcome suggestions for additional topics by **1st April 1991**. The inclusion of topics in the final programme will depend on the level of interest shown by offered papers. The Congress language will be English, but papers may be accepted in French if simultaneous translation facilities are available.

The Proceedings of the Congress will be published in a single volume.

It is also hoped to run afternoon/evening workshops of help establish the formation of Specialist Groups within the Federation. Any individual or group interested in organising/establishing a specialist group should contact the General Secretary of the Federation. To receive the First- Circular, please send an **expression of interest** in attending the Congress, and an indication as to whether you intend to present a paper or poster to the Congress Office, by **1st April 1991**. Further information can also be obtained from this Office or from the Programme Secretary of the Federation

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FISH COMMUNITIES AND FISHING IN A FLOODPLAIN LAKE OF CENTRAL AMAZONIA*

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MOTS CLÉS : Amazone, plaine inondable, communautés de poissons, pêcheries.

KEY WORDS : Amazon, floodplain, fish communities, fishery.

RÉSUMÉ

PEUPELEMENTS DE POISSONS ET PÊCHE DANS UN LAC DE PLAINE INONDÉE EN AMAZONIE CENTRALE.

L'analyse synthétique des résultats d'une étude multidisciplinaire menée sur une île de la plaine inondée d'Amazonie centrale et sur son lac intérieur débouche sur un certain nombre d'observations. La production piscicole actuelle est largement inférieure au potentiel estimé. La différence peut néanmoins varier amplemment d'une année à l'autre. La composition des captures est sensiblement différente de la composition du peuplement. Outre qu'il existe dans le peuplement de nombreuses espèces de petite taille dont l'exploitation n'est pas pratiquée, il y a nettement un désintérêt de la pêche pour certaines espèces exploitables abondantes. Le régime de crue affecte, de manière prononcée les comportements de pêche. Il affecte aussi les captures par effort qui, du fait de larges changements de la densité des poissons dans le volume d'eau, ne sont pas proportionnelles à l'abondance en poisson. Lorsque la hauteur d'eau moyenne sur une année augmente, la biomasse totale de poisson augmente aussi, mais les captures par effort diminuent. Il est conclu que la production piscicole est soumise à un certain nombre de contraintes physiques, biologiques, écologiques, culturelles et économiques qui limitent l'activité de pêche. La situation étant complexe, des études minutieuses sont encore nécessaires avant de pouvoir proposer un aménagement adapté.

SUMMARY

The synthesizes analysis of the results of a multidisciplinary study, carried out on an island and its inner lake in a central Amazonian floodplain, leads to a certain number of observations. Current fishery production is below its estimated potential. The difference, however, can vary greatly from one year to another. The composition of the captures differs significantly from the composition of the fish population. Aside from the many species not captured because of their small size, there is a clear disinterest for certain exploitable and abundant species. Flooding markedly affects fishing habits. It also affects catch per unit of effort which, because of large changes in fish density in the volume of water, are not proportional to the actual abundance of fish. When the average yearly water level is high, the total fish biomass is also high, but catches per unit of effort are low. It is to be concluded that fishery production is subjected to a certain number of physical, biological, ecological, cultural and economic constraints which limit fishing activity. Because of the complex situation, exacting studies are still necessary before appropriate management can be proposed.

INTRODUCTION

Floodplains of tropical rivers are generally considered very productive environments. For their aquatic component and its terminal production, the above assumption is supported by the observed higher fish yields in rivers with extensive floodplain than in the ones with a more de limited bed (WELCOMME, 1974 ; 1979). The Amazon River belongs clearly to the first category with an extensive floodplain representing about 2.9% of the whole basin (about 210 000 km²). In the Brazilian Amazon, fish yield

is based primarily on floodplain productivity (PETREIRE, 1982 ; BAYLEY, 1981 & 1982). With the increase in fishing pressure on the stocks, some indications of over-fishing have been detected for individual species (MERONA & BITTENCOURT, *in press*). However, BAYLEY (1981, 1982) suggests that there is a broad overall under-exploitation of the fish resource in the Brazilian Amazon occurs. This paper is an attempt to resolve this contradiction based on a particular case : the « Lago do Rei », a floodplain lake in

central Amazonia. This study was part of a multidisciplinary project developed on the lake and the island which surrounds it, between 1985 and 1987 (ORSTOM-INPA-CEE, 1988).

METHODS

THE STUDY AREA

Careiro Island is a large alluvial island, located in front of the meeting of the waters of « Rio Negro » and « Rio Solimões » (FIG. 1). The island is approximately 200 km² and includes a large lake named « Lago do Rei », as well as number of secondary water-bodies. This aquatic system is connected to the Amazon River by a canal, about 20 km long. The water level in the lake follows the water level fluctuations in the river.

DATA COLLECTION AND TREATMENT

Fish communities

The detailed methodology is described by MERONA *et al.* (1988). Experimental fishing with a battery of 13 gill nets of different mesh size was conducted every 2 months between February 1986 and June 1987. At each collection date, we sampled the different habitats which could be recognized in a predetermined zone (shown on FIG. 1). The specific and total capture was expressed in catch per unit of effort (CPUE = catch in number or weight per 1,300 m² during 24 h.). Biomass indices were calculated by correcting the CPUE of the samples by the estimated volume of the lake at the time of collection (see GUILLAUMET *et al.*, 1988, for the detail of volume estimation).

Fishing

The study is based on daily fish landing data collections in two points : the central market of Manaus city and a traditional settlement on the north coast of Careiro

Island (« Terra Nova »). The detailed methodologies can be found in PETRERE (1978) for Manaus market and MERONA and THERY (1988) for the island. These data collections provide information on specific landings, gear used, local of fishing and effort.

Production estimates

Estimates of production are based on the work of BAYLEY (1982). It is assumed in this study that the potential yield lies between 0.3 and 0.5 times the biological production according to the model of GULLAND (1970) generalized to an exploited « multispecific stock ». The total fish yields of « Lago do Rei » are calculated from MERONA & THERY (1988). The surface and the volume of the lake are estimated from a simple model developed elsewhere (GUILLAUMET *et al.*, 1988).

ACTUAL CATCH VERSUS POTENTIAL YIELD

The values of total yield observed for the two years of study are markedly lower than the potential yield (TABLE I). However the difference is much less pronounced in the 1985/1986 season where the yield represents 16.5% of the lowest estimation of the potential.

The way biomass and production were calculated implies a direct proportion between the production estimates and the mean surface area of the lake during the hydrological year. Some kind of relation may indeed exist. On one hand, the lower the level in the low water period, the higher the natural and fishing mortalities. On the other hand, a high water level favors the recruitment of the young in the community and a rapid growth. However, it is probable that biomass and production are also related to previous years hydrological regimes which could affect the abundance of age classes of two or more years. This effect is probably very important for the potential yield because fishing pressure is much more directed towards the older fish.



FIG. 1 - Map of the study area. Square shows the experimental fishing zone. Description of the zone d'étude. L'encadré représente la zone de pêche expérimentale

	1985/1986	1986/1987
Lake area (km ²)	80.57	93.63
Biological Production (t/year)	22,560	26,216
Mean Biomass (t)	12,891	14,981
Potential Yield (t/year)	6,678-11,280	7,865-13,108
Actual Yield (t)	1,115	552

TABLE I.- Estimates of fish production, potential yield and actual yield for the « Lago do Rei ». Estimations de la production biologique, du potentiel de pêche et des débarquements actuels des poissons du « Lago do Rei ».

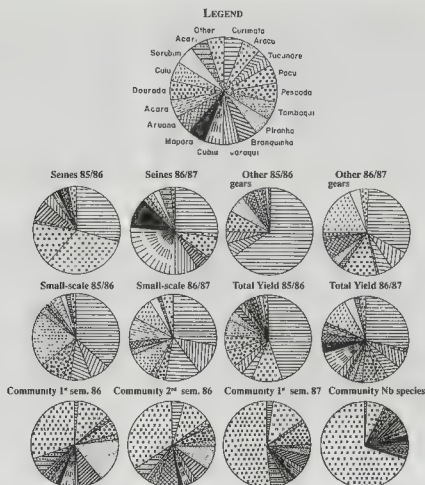


FIG. 2.— Catch composition and fish community composition for the 85/86 and 86/87 hydrological seasons in the « Lago do Rei »

Composition des captures et composition de la communauté de poissons pour les saisons hydrologiques 85/86 et 86/87 dans le « Lago do Rei ».

Another consideration concerns how much of the biological production can be considered as potentially exploitable. BAYLEY (1982) estimates at 134 000 t the part of the production of fish greater than 25 cm in length which are basically those recruited by the fishery. This value represents 36.7 % of the total biological production and is comparable with the predictions given by the model of GULLAND (1970).

CATCH COMPOSITION VERSUS COMMUNITY COMPOSITION

Three types of fishing activities contribute to the total yield.

- A seine fishery in the canal between the lake and the river captures the migrating fishes.

- A « multi-gear » fishery using gill nets, fishing-rod, trident and harpoon, is developed in the lake itself.

- A small-scale local fishery with very low investment, takes place in the lake in areas near the settlements. In total captures, 17 fish products are significantly repre-

sented (FIG. 2). One of them, the « curimata » (*Prochilodus nigricans*) was clearly dominant during the two seasons studied. Some products appear sporadically like the « aracu » (*Anostomidae spp.*), the « cubu » (*Anodus spp.* and *Eigenmannina spp.*) and the « mapara » (*Hypophthalmus spp.*). The seine fishery is responsible for these captures. In the lake itself, catch composition is somewhat constant from one year to the next although in 1986/87 a significant decrease of the contribution of « curimata » and a parallel increase in the relative importance of « cuiu » (*Pseudodoras niger*) are observed. The catch composition of the small-scale local fishery shows a great proportion of some very high priced species like the « tambaqui » (*Colossoma macropomum*), and the « tucunare » (*Cichla monoculus*).

In the fish community, these 17 fishing products represented together always less than 75 % of the mean biomass estimated over 3 six-month periods. The exploited products correspond to approximately 41 species, which represents only 30 % of the total number of species captured in the lake. The difference between the relative importance of the fishing products in biomass and in number of

species suggests that a great number of non-exploited species are small-sized and could not be caught with the gears currently in use. Considering only the exploited products, it can be seen that some species are heavily exploited in spite of low representation in the community. It is especially true with the « curimata » whose distribution in the lake is limited to the marginal areas covered with floating meadows (MERONA *et al.*, 1988). On the contrary, the « aracu » and the « piranha » (*Serrasalmus spp.*) are poorly exploited despite their great abundance in the fish community.

FISHING BEHAVIOR AND HYDROLOGICAL REGIME

Global fishing intensity as well as the use of specific gear (both expressed by the number of trips to the lake) are very variable on a monthly basis (Fig. 3). The use of seine is irregular and seems to be opportunistic, taking advantage of local and time-limited fish concentrations. The frequency of the trips into the lake, using gillnet, fishing-rod, trident, harpoon or a mixture of these gears is cyclic and regular, showing a maximum during the low water period and a minimum during the high water period. There are two possible explanations for the low degree of acti-

vity in the high water season. On one hand, when the water rises in the river, it enters in the lake by the canal, carrying with it a great amount of trunks and other floating plant material which can eventually obstruct the channel and prevent the entry of the fishing boats. On an other hand, the increase in lake volume and the inundation of large marginal areas allows many commercial species to take refuge in the flooded forest or in the floating vegetation where fishing on a large scale is not possible. Because of its ability to reach to access the marginal areas, the small-scale local fishery is a much more constant activity.

TIME VARIATIONS OF CATCH BY EFFORT AND BIOMASS

The catch per unit of effort (CPUE) of the 3 different fisheries present large seasonal variations (Fig. 4). The CPUE of the seine fishery, which can attain high values of 350 kg by fisherman and by day, shows two maxima in the hydrological year, one during the falling of the waters and the other in the beginning of the flood. These changes correspond to the two types of lateral fish migration in the system described by COX FERNANDES & MERONA (*in press*). The variations of CPUE in the two other types of fisheries are almost parallel. The values are much lower than those of the seine fishery and there is a maximum during the low water period. For all fisheries, the mean value of CPUE is lower in 1986/1987 than in 1985/1986. The CPUE of the experimental fishing shows a very sharp increase in the period of low water, but is nearly the same in the two periods of rising water.

The variations of biomass appear very different compared to those of CPUE. A very rapid increase during the inundation was observed in the two years of this study. However, a parallel decrease did not occur during the falling waters in 1986 resulting in much higher biomass values in 1987.

These observations suggest that CPUE cannot be used as abundance indices in that particular case. They are, in fact, proportional to the density of fish in the environment which is in turn dependent on the volume of water present in the studied area. Because of the large interannual variations in the hydrological regime, this volume cannot be considered constant on a yearly basis.

GENERAL CONCLUSIONS

The low value of the total yield from the « Lago do Rei » compared with the estimated potential yield, would suggest that the fisheries under-exploit this fishing ground. However, the great difference observed between the 2 years of this study demand caution in drawing this conclu-

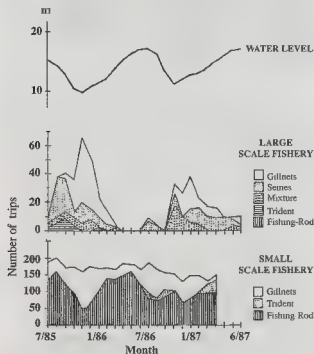
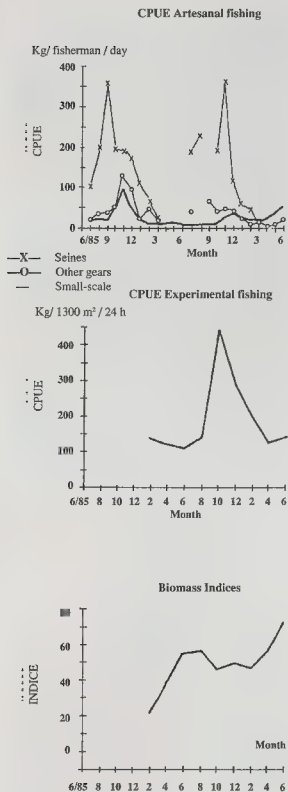


FIG. 3.- Changes in the water level of the Amazon River and in the number of trips in the fisheries of « Lago do Rei » for the 85/86 and 86/87 hydrological seasons. Evolution de la hauteur d'eau dans l'Amazonie et du nombre de voyages de pêche pour les pecheries du « Lago do Rei » pendant les saisons hydrologiques 85/86 et 86/87



sion. A very dry year may provoke low production together with high natural mortality. The fishing itself, as has been shown, takes advantage of the low waters and fishing mortality may, in this hypothetical case, be catastrophic, even with unchanged fishing intensity.

Regardless of the degree of under-exploitation, it is obvious that the fishery has a very limited number of target species although almost all the medium and large size species could eventually be caught. This observation can be explained by the existence of a great variety of constraints limiting the fishing activity. They are related to number of factors.

- 1) Hydrological characteristics : the vegetation carried by the rising waters can prevent access to the fishing ground. In addition, the great increase in the volume of the water during the high water season results in a reduction of gear efficiency. The use of certain categories of gear is also limited by the characteristics of the water-body.
- 2) Fish morphology : some very elongated fishes like the « aracu » or the « mapara » escape from the gillnets used by the fishery. Smaller mesh size cannot be used because they will capture small size fish which cannot be sold.
- 3) Fish behavior : some species (particularly piranhas) enter in direct competition with the fisherman, attacking the fish captured in the gill net and causing heavy losses.
- 4) Fish ecology : a number of species take refuge in the marginal and inaccessible areas of the flood-plain. Lateral migration does not seem to be a regular phenomenon for some populations.
- 5) Cultural and economical factors : in the region, there are many superstitions about fish. A number of species are not acceptable to the consumer or bring a low price in the market.

This situation lead the fisherman to concentrate his effort on a few species whose stocks could be threatened in the short or medium term. This appears to be the case of the « pescadas » (*Plagioscion spp.*) which were intensively fished in the period 1976-1979 (ANNIBAL, 1982) and are now quite scarce.

In these conditions management of the fishery is impossible on the base of too general data. The annual variation in production must be monitored over a long time period in order to determine a maximum value for the potential yield. There is also an urgent need for detailed studies on the exploitable species in order to determine their contribution to community production and their relationships with other species.

FIG. 4. — Changes in the catch per unit of effort in the fisheries and in the experimental fishing in the « Lago do Rei » for the 1985/86 and 1986/87 hydrological seasons.

Evolution des captures par effort de pêcheries artisanales et de la pêche expérimentale dans le « Lago do Rei » pendant les saisons hydrologiques 1985/86 et 1986/87

Acknowledgments

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ADVANTAGES OF NEOTROPICAL FISH SPECIES FOR AQUACULTURE DEVELOPMENT IN AMAZONIA*

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MOTS CLÉS : Aquaculture, Amérique latine, poissons indigènes

KEY WORDS : Aquaculture, Latin America, indigenous fishes.

RÉSUMÉ

INTÉRÊT DES POISSONS NÉOTROPICAUX POUR LE DÉVELOPPEMENT DE L'AQUACULTURE EN AMAZONIE.

La production de l'aquaculture en Amérique latine est plutôt modeste : en 1985, elle ne représentait que 0,6% de la production mondiale. Pratiquée depuis les années 40, l'aquaculture latino-américaine s'est essentiellement focalisée sur des espèces non indigènes, comme la carpe, le tilapia, les salmonides. Ces dernières années, une plus grande attention a été portée à la culture d'espèces indigènes. Cette nouvelle orientation, fortement dynamisée par le séminaire FAO de 1976 en Uruguay, est analysée dans le présent article.

SUMMARY

The aquaculture production in Latin America is almost entirely disregarded. From the total world fish yield in 1985, only 0.6 % was produced in Latin American aquaculture. Although aquaculture in this continent has been practiced since the 1940's with mainly non-indigenous species like carp, tilapia, salmonids, in recent years more attention has been drawn to the culture of aquatic organisms in general and to the culture of indigenous species in particular. This new trend in development, was given a strong impulse by the 1976 FAO seminar in Uruguay, and will be reviewed in this paper.

INTRODUCTION

Latin America's aquaculture production is very low, accounting for only 0.6 % of the world's yield of 10.5 million tons in 1985. Most of it is produced on *Penaes* farms, mainly in Ecuador and Central America. The importance of aquaculture in Latin America is relatively insignificant compared to its marine fisheries, which land about 9 million tons annually and accounting for 12.5 % of the world catch. The special geographic situation of this continent together with the feed habits of its population and a lack of aquacultural tradition lead in former years to another way of producing protein namely, cattle farming. Furthermore, limitation of natural fish resources both in fresh and in sea waters, plus the increasing costs for fishing and the change in maritime laws have resulted in focusing more attention on aquaculture in recent years.

In 1976, a FAO status seminar on the contemporary development of aquaculture in Latin America was held in

Uruguay. It was reported that aquaculture has been practiced since 1940's. Early experiences were gained in the culture of fish by stocking natural and artificial bodies of water. Some of the fish raised were native species. More intensive forms of aquaculture, however, employed exclusively non indigenous species, such as tilapia, carp, and salmonids.

The 1976 conference was so stimulating that during the following ten years some progress has been made in the improvement of South American aquaculture. There were very successful attempts to culture indigenous species during the last years which have led to new development for fishculture (SAINT-PAUL, 1986). This paper will present a short summary on the advantages of using indigenous species for aquaculture prospects in the tropical areas of Latin America.

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TAXONOMY AND BIOLOGY

The genus *Colossoma* with what were formerly three species has recently been revised into the genera *Colossoma* and *Piaractus* (GÉRY, 1985). Two of three species, *C. macropomum* and *P. brachypomus* (synonym *C. brachypomum*) occur in the Orinoco and Amazon River systems while *P. mesopotamicus* (synonym *C. mitrei*) inhabits the Parana-Uruguay river. The common names of *C. macropomum* and *P. brachypomus* are tambaqui and pirapitinga in Brazil, cachama and morocoto in Venezuela, gamitama and paco in Peru, and cachama negra and cachama blanco in Colombia, respectively. *P. mesopotamicus* is known as paco or pacu-caranha in Brazil.

C. macropomum, the largest species, can weigh up to 30 kg. Adults are considered to be exclusively frugivorous, while juveniles are omnivorous, feeding also on zooplankton (GOULDING & CARVALHO, 1982). Studies on *P. brachypomus* (20 kg maximum weight) indicate that the adults do not display such an exclusively frugivorous diet (GOULDING, 1980). *P. mesopotamicus* (7 kg maximum weight) shows a similar diet (SILVA, 1985).

In the Central Amazon region the Characid *Brycon cephalus*, called matrinhã, seems to be most promising for aquaculture purposes (SAINT-PAUL, 1986). For the Peruvian Amazon region it is *B. erythropterus*, locally called sabalo roja. They can reach a weight of about 5 kg and are considered as omnivorous with, however, a large amount of plant material in the diets (MENEZES, 1969; GOULDING, 1980).

ADAPTATIONS TO OXYGEN DEPLETION

Diurnal O_2 variations with period of severe hypoxia during the night occur frequently in tropical fish ponds under extensive and semi-intensive culture conditions with minimal water exchange. The day 150 % supersaturation may be reached, while at night severe O_2 -depletion with concentrations below 5 %, corresponding 0.5 mg/l, are frequent.

It was first noted for several relatively small tropical teleosts, such as cyprinodonts and poeciliids, that they use the millimeter-thick surface layer of the water during periods of low oxygen for gill respiration. Due to diffusion from the atmosphere, this surface layer is relatively rich in O_2 . Further investigations demonstrate that this emergency respiration, which is commonly called « aquatic surface respiration » (ASR), is rather widespread among relatively small tropical fish species.

Extended ecological and experimental investigations proved the same display of ASR for some large neotropical characoids (BRAUM & JUNK, 1982; SAINT-PAUL & BERNARDINHO, 1988; SAINT-PAUL & SOARES, 1988). At O_2 -concentrations of 0.5 mg/l the fish swim to the surface in order to practice ASR (SAINT-PAUL & BERNARDINHO, 1988;

SAINT-PAUL & SOARES, 1988). What was completely different and unknown for these species, is that a dermal swelling at the lower jaw appears after longer exposure to low O_2 -concentrations. Such an unusual kind of lip formation is demonstrated so far for Characoids of the genera *Colossoma*, *Piaractus*, *Brycon*, *Mylossoma*, and *Triportheus*. After subsequent aeration of the water, the lip slowly retrogresses to its original size and the fish returns to its normal swimming position. As the histological sections show no unusual aggregations of blood vessels the dermal extension has obviously only a hydrodynamic function for utilizing the oxygen rich surface layer of the water for respiration.

Floodplains as well as tropical fish ponds are very often partly covered by floating macrophytes e.g. *Eichhornia* or *Pistia*. Fish population usually aggregate between and under these macrophytes. During normal O_2 concentrations, both *Brycon* and *Colossoma* prefer the macrophyte cover, as demonstrated experimentally. By using sonar it was demonstrated that during the night, when the O_2 concentration becomes extremely low, there is an increased fish density in the open water where the fish display ASR, thus indicating an O_2 -induced diurnal pattern of horizontal migrations between the zone of macrophyte cover and the open water (SAINT-PAUL & SOARES, 1987).

Supplemental experimental investigations seem to indicate that *C. macropomum* can deviate from this migration pattern. During longer periods of O_2 -depletion, the fish return to the region of macrophytes and survive there, apparently without the usual kind of ASR. Mortality studies performed in net cages exposed in a natural lake environment, confirm its ability to survive severe hypoxia beneath macrophyte cover (SAINT-PAUL & SOARES, 1987). This makes it very likely that *C. macropomum* can utilize the oxygen released from the macrophyte's rhizoid system, which was positively proved for several emersal waterplants. All other species investigated are not able to survive O_2 depletion beneath macrophyte cover.

ARTIFICIAL REPRODUCTION

None of the species have yet been induced to breed naturally in captivity. However, reports of successful hypophysation experiments on *Colossoma*, and *Piaractus* have already been made from Brazil, Venezuela, Peru, and Panama (e.g. BERMUDEZ *et al.*, 1979; WOYNAROVICH, 1986). Positive results are reported as well with combined dosages of hypophysis extract and a synthetic GHG hormone, or by the applications of the gonadotrophic hormones SGG 100 and LH-RH. The hypophysal material is injected intermuscularly in two doses. Females, weighing at least 7 kg, receive 5 mg of hypophysal dry weight per kg, after being prepared by a first injection with about 10 % of

this dosage. Males are initially given 0.5 mg/kg and then a subsequent dosage of 1.0 mg/kg. Females weighing between 10 to 15 kg lay between one and two million eggs. Eggs are fertilized dry. The incubation period at 26-29° C is 17-23 h. The semi-pelagic eggs can develop successfully in a Zoug jar. The yolk sac stage lasts 4 days, and the first feeding occurs 5 days after hatching. The procedure of artificial reproduction of *P. brachypomus* and *P. mesopotamicus* is similar (GODINHO & GODINHO, 1986).

NUTRITION AND GROWTH

There is only limited information available on the nutritional requirements of *C. macropomum*, which is summarized by SAINT-PAUL (1986). This species can live on both natural and artificial food. Artificial feed should contain about 30 % raw protein, the main protein source may come exclusively from plant material. The knowledge of the nutrition of *P. brachypomus* is even more sketchy. Some investigation about the protein requirements of *P. mesopotamicus* are available. The results, however, are contradictory. A lot of research still is necessary in this area.

Pond monoculture with *C. macropomum* has been successfully practiced in Brazil, Venezuela, Columbia, and Peru (SAINT-PAUL, 1986). The stocking density ranged from 1180 to 10000 fish/ha. The maximum annual production attained 9.2 t/ha. In Venezuela a first commercial fish farm with an annual production capacity of 300 to 400 t was established. However, for unknown reasons, production has changed to *Marcobrachium rosenbergii* recently. Fry takes about 14 months to grow to marketable size of 2-3 kg.

Polyculture involving this species together with tilapia or carp was conducted in Brazil. At a combined stocking density of 10.000 fish/ha, a production of 8.9 t/ha was achieved.

Preliminary reports on cage culture although not very encouraging are available from Venezuela (DARMONT & SALAYA, 1984).

The growth rate of *P. brachypomus* seems to be less promising. The greatest production, 8.3 t/ha per year, was achieved at a stocking density of 10.000 fish/ha (DA SILVA *et al.*, 1980).

Under extensive and semi-intensive culture conditions, *P. mesopotamicus* grew to a weight of 577 g after a year, corresponding to an annual production of 5.9 t/ha (FERRARI & BERNARDINHO, 1984). However, *P. mesopotamicus* still shows satisfactory growth rates at temperatures between 15 and 20° C. Hybrids of *C. macropomum* and *P. mesopotamicus* are supposed to combine excellent growth rates with low temperature tolerance.

Brycon spp. as well as artificially reproduced by hypophysation (ECKMANN, 1984).

Artificial diets should contain about 35 % protein (SAINT-PAUL & WERDER, 1981). Up to 20 % of the feed could be substituted using dried water hyacinth without any reduction in growth (SAINT-PAUL *et al.*, 1981). In pond experiments, best growth rates of more than 500 g per year, corresponding to an annual production of about 2 t/ha, were achieved under semi-extensive conditions. Under extensive rearing conditions fish grew from 2 g to 1096 g in 476 days (SAINT-PAUL, 1986).

DISCUSSION

South America possess the richest ichthyofaunal diversity among the continents. In the Amazon region alone, it is estimated that over 2.000 species occur. In spite of this great potential, it was initially believed that the establishment of pond culture facilities would succeed most rapidly if the widely raised species of warm water aquaculture, such as tilapia and carp were introduced. The obvious reason for this was the lack of knowledge in cultivation of native species. Thus exotic species, like the tilapia, were introduced without any control. These activities will and/or already have created, great ecological problems, as the introduced species may escape and become subsequently adapted to natural habitats, thus modifying indigenous bio-communities : the use of such species would provide only very short-term advantages.

The review provided here of the attempts at using endemic fish species clearly demonstrates that South American fishculture in climatic areas of the tropical rain forests of Amazonia and the savannah can best be developed in the future using any of the mentioned species.

A major goal in aquaculture development, especially in the tropical zone, is to meet the basic needs of the local people. Considering the low standard of living of the local population and the special socio-geographical situation, fish culture can succeed only when it is based on fish species suitable for the extreme limnological conditions that prevail in tropical ponds. Furthermore, it is important that the species chosen are able to feed on plant material, including the waste products of agriculture. They also must produce offsprings even through artificial induced methods in adequate numbers. The species mentioned in this paper fulfill nearly all of these requirements. South American aquaculture development is now concentrating more on these local species. Based on the available production figures, the average yield from a semi-extensive monoculture of *Colossoma* is 3t/ha-yr. Thus, a 0.2-ha pond area is sufficient to supply nearly the entire daily requirements of an average family of ten persons. However, there is still a serious lack of knowledge on controlled breeding and nutrition.

It is remarkable that so few investigations of polyculture systems have so far been undertaken. By using this culture technique, which has shown great success, especially in Asia, a considerable increase in the yield may be expected. Attempts at raising *Colossoma* and tilapia in Brazil and experiences with numerous endemic species in Venezuela seem to confirm this potential. Systematic studies on different polyculture systems are however still necessary.

The further development of fish culture in South America will depend firstly on its feasibility. During the early stage of development, biological questions had the priority, but in the future the economics of the production will be more important. Aside from the initial capital outlay for pond construction, operating costs for the stocking material and the feed must also be considered. Because the fishes for stocking are only produced exclusively in central breeding facilities, an urgent requirement is to calculate the economics of operating such facilities. The lack of these basic information also explain the nearly complete absence of any commercial fish farming in South America.

In summary, because of excellent growth rates, low feeding cost, and tolerance to low oxygen conditions of the native fish species mentioned, all requirements have been fulfilled and thus paved the way to establish aquaculture projects in the near future as backyard fish farming and/or main business undertakings.

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